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TECHNICAL EVALUATION PROGRAM ANALYSIS PROCEDURES (TEPAP).(U)
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RADC-TR-78-120
Phase Report
May 1978

TECHNICAL EVALUATION PROGRAM ANALYSIS PROCEDURES (TEPAP); RESEARCH REPORT 1-77

R. L. Feik

SUNY at Buffalo

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (18) RADC-TR-78-120 — 2. GOVT ACCESSION NO. (9) Research rept.,	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) TECHNICAL EVALUATION PROGRAM ANALYSIS PROCEDURES (TEPAP), [redacted]	5. TYPE OF REPORT & PERIOD COVERED Phase Report
	6. PERFORMING ORG. REPORT NUMBER N/A
7. AUTHOR(s) (10) R. L. Feik	8. CONTRACT OR GRANT NUMBER(s) (15) F30602-75-C-0122
9. PERFORMING ORGANIZATION NAME AND ADDRESS SUNY at Buffalo 4232 Ridge Lea Road Amherst NY 14226	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ~~9RCW~~ (16) 95670017 (17) 00
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (RBC) Griffiss AFB NY 13441	12. REPORT DATE (11) May [redacted]78
	13. NUMBER OF PAGES 119
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same	15. SECURITY CLASS. (of this report) UNCLASSIFIED (12) 118p.
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

63203F

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer:
Jacob (NMI) Scherer (RBC)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Communications Systems
System Performance
Systems Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The DCA sponsored Technical Evaluation Program (TEP) has yielded many outputs, but has failed to provide the products desired by engineering personnel. The lack of an analysis procedure has been one, if not the prime reason for this disappointing record. Other reasons include excessive quantity of tests, inconsistency of the measurements, absence of several specific and mandatory test assessments, and lack of specific TEP goals.

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This report describes a TEP analysis concept and procedure, and demonstrates the application to a specific link. The procedure permits absolute numerical correlation of the TEP data and permits filling in of some absent data, or correction of bad measurements.

During this study, a new technique was developed that relates idle channel noise, baseband loading, and link noise power ratio. Many of the statistical studies of PMP now can be evaluated deterministically. The Technique applies equally well to multi-hop paths. The new technique allows direct comparison f TEP data with Performance Monitoring Program (PMP) data, and should replace the present PMP analysis procedures.

This report is one of two studies related to the TEP. The other "Evaluation of TEP" describes a streamlined more cost effective approach to the link assessment problem. These reports are to a degree mutually supporting, although each is complete in itself.

PREFACE

This effort was conducted by R L Feik in association with State University of New York under the sponsorship of the Rome Air Development Center Post-Doctoral Program for the Defense Communication Agency. Mr. R I Hughes of the Defense Communication Engineering Center, DCA was task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Department of Electrical Engineering) act as prime contractor schools with other schools participation via sub-contracts with the prime schools. The U S Air Force Academy (Department of Electrical Engineering), Air Force Institute of Technology (Department of Electrical Engineering), and the Naval Post Graduate School (Department of Electrical Engineering) also participate in the program.

The Post-Doctoral Program provides an opportunity for faculty at participating universities to spend up to one year full time on exploratory development and problem-solving efforts with the post-doctorals splitting their time between the customer location and their educational institutions. The program is totally customer funded with current projects being undertaken for Rome Air Development Center (RADC), Space and Missile Systems Organization (SAMSO), Aeronautical Systems Division (ASD), Electronic Systems Division (ESD), Air Force Avionics Laboratory (AFAL), Armament Development and Test Center (ADTC), Air Force Communications Service (AFCS), Aerospace Defense Command (ADC), HQ USAF, Defense Communications Agency (DCA), Navy, Army, Aerospace Medical Division (AMD), and Federal Aviation Administration (FAA).

Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC, telephone AV 587-2543, Comm. 315-330-2543.

The author wished to thank Mr. Hughes, Mr Bugg, and Mr Dunn, all of the DCA DCEC, for their continuing supoort, and Mr R H Levine, Asst. Director of DCEC, for his direction and helpful suggestions all through this effort.

CONTENTS

ILLUSTRATIONS

TABLES

APPENDIX

T. E. P. ANALYSIS PROCEDURES

I. INTRODUCTION

A. General

The DCA has sponsored the Technical Evaluation Program (T.E.P.) for a number of years. This program has yielded many outputs, nevertheless, the T.E.P. products have failed to provide the outputs desired by many of the personnel responsible for the engineering of the DCS. There are several reasons for this lack of obvious outputs. These including the absence of an analysis procedure to easily extract the information from the T.E.P. bulk data, the excessive quantity of measurement data produced by the T.E.P. procedures, the general inconsistency of much of the data, the absence of several specific and mandatory measurements necessary for the complete data analysis, and void of specific goals for the program. There is also a philisophical difficulty - the deletion of the requirement for gathering meaningful "preliminary data" to portray the "as found" equipment/link operational condition. This information is not needed to embarrass or finger point, but rather to permit the system engineers and O & M personnel to see the real life environment faced by operational users and by new devices and hardware engineered or procured off-the-shelf for application in the DCS. The users do not see a single link after it has been TEP'ed. They see the total system, most of which is considerably degraded from the post T.E.P. characterization. There is some incomplete "preliminary data," presently gathered and maximum use is made of this information in the analysis concept.

In spite of these obvious and correctable T.E.P. constraints, proper analysis of the data sheds much light on the status of the link, and highlights difficulties that require engineering attention. Further, issues of interest to the Operations and Maintenance (O&M) Agencies in the day to day management of their portion of the DCS also are extracted. Much of the reduced data from T.E.P. can be summarized to form unique information needed for the engineering, development, and implementation of the DCS System and its Performance Assessment and Control.

There is a new technique presented in this study that was derived during the work on this contract. It offers a new insight into the analysis and visualization of the performance of links. It also is highly informative in portraying the performance status of long multi-hop links. This new technique is a new scientific way to combine key performance parameters onto a single chart - no average of averages! The output presents the link or multi-link performance in a format easy to grasp. It presents the results in a manner that accounts for the varying numbers of active channels in the links and the changing usage of the channels over the links. An "Equivalent Fully Loaded Link Performance" figure is derived and "db below like new" is easily seen.

B. Analysis Approach.

Figure 1-1 portrays a radio link, and shows the four general elements of the link:

I. the RF related structure
II. the transmitter and receiver
III. the multiplex
IV. the interface cables and connectors
V. end-to-end link performance

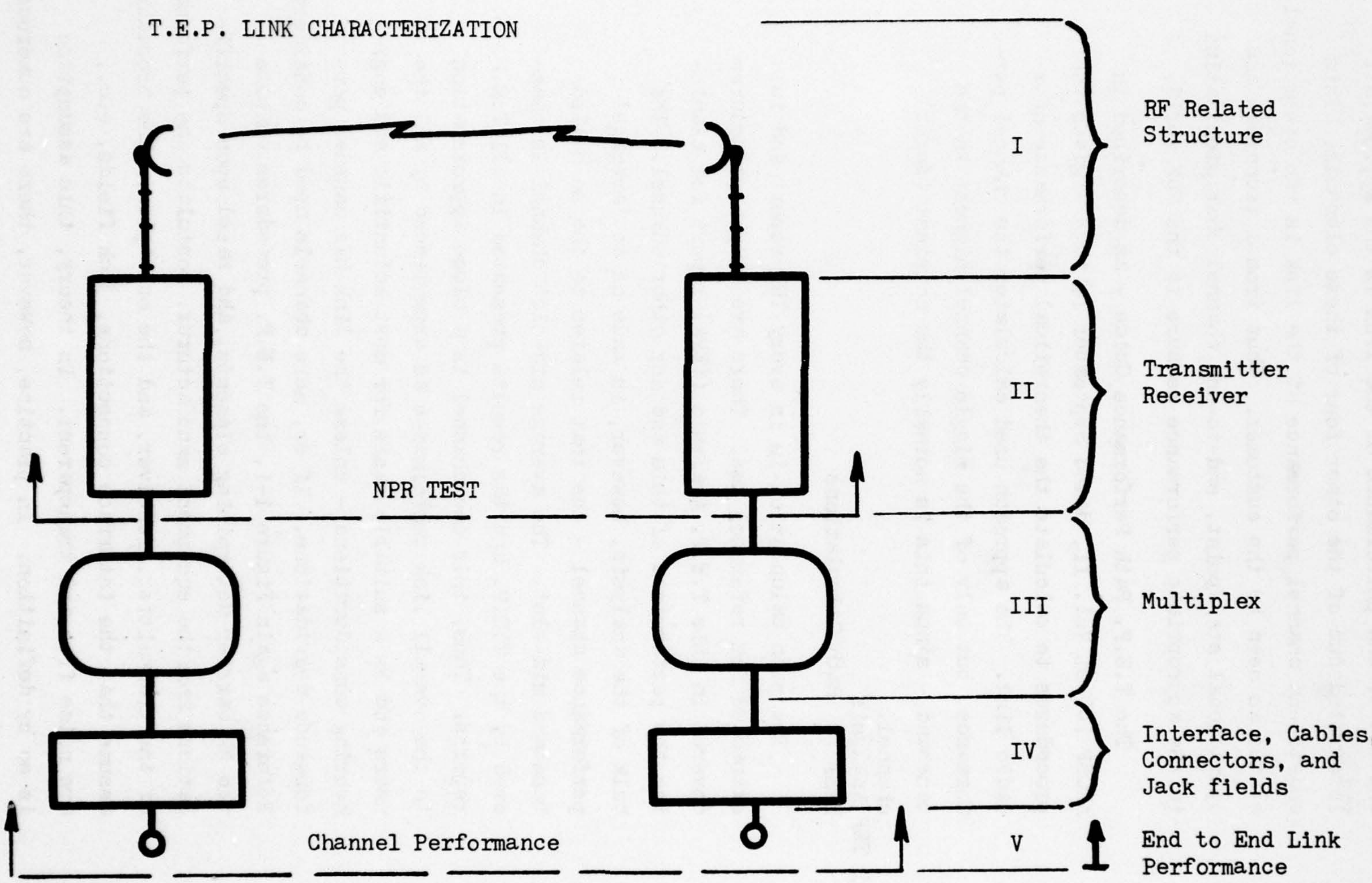

T.E.P. LINK CHARACTERIZATION
NPR TEST
Channel Performance
I
II
III
IV
V
RF Related Structure
Transmitter Receiver
Multiplex
Interface, Cables, Connectors, and Jack fields
End to End Link Performance

Fig 1 - 1

The end-to-end performance of the link is the appropriate integrated sum of the other four of these elements. This end-to-end channel performance of the link is the operational status as seen by the customer. Thus from a technical and operational standpoint, end-to-end channel characterization is the appropriate performance measure in the FDM world.

The T.E.P. Path Performance Guide - as described in AFCSP 100-61 Vol. II, dated September 1, 1972 - gives the procedures to calculate the theoretical performance of a radio link. The approach used calculates the channel performance, but only of the single channel highest in the baseband - since this is normally the noisiest (worst) channel.

II TEP Analysis

STEP 1 Path Calculations

The path calculation is in every TEP report and is extracted for reference use. There are simple procedures covered in this T.E.P. Analysis (TEPA) report for examining the performance of this and any other channel. The bulk of the analysis, however, is made on an 'average' performance channel - one that relates to the so called baseband mid-slot. The average mid-slot channel is measured by the T.E.P. and the results presented in all T.E.P. reports. Thus, this one channel is a close approximation to the overall link performance as experienced by all the users and is a suitable basis for most scientific and engineering considerations - unless the link has unusual performance degradations. If so, more channels need be considered. Reference again Figure 1-1, the T.E.P. procedures compute the RF carrier determining elements, and based upon specifications from the equipment manufacturer, postulate the performance of the transmitter, receiver, and the multiplex. The procedures assume that the interface connections, jack fields, etc., are noise free and transparent. In theory, this assumption is so by definition. In practice, however, there are numerous examples where this simplifying assumption is not true. These exceptions are detected by the described analysis procedures.

STEP 2 Data Extraction

The analysis approach used is straight forward and starts with the extraction of those needed parameters from the theoretical path performance calculations and entering in a Table format - see Table 2-1. Where possible, these parameters are subject to direct comparison with measurements taken by the T.E.P. teams such as receiver bandwidth, noise figure, etc. Thus, often direct validation of the theoretical/engineering data is possible. Other data are inferentially verified. These parameters are the only ones that are needed for proving or establishing the performance of the four sub-elements of the link, and the total end-to-end circuit quality achieved. Much of the T.E.P. data is of secondary or tertiary use and some is of no demonstrated value at all.

Unfortunately, the practical facts of life, constraints of technology, and T.E.P. measurement steps do not permit direct characterization of any of the four major link sub-elements. As will become clear in the next chapter, the described analysis approach does permit validation of the performance of the RF determining related structure and the transmitter/receiver sections completely - although indirectly. The multiplex and audio interconnect portions are less precisely assessed in the TEP and in some cases problems are identified but may not be isolated. Engineering, installation, or maintenance problems are surfaced but may be unresolved. The T.E.P. team chief letters are sometimes illuminating on these type problems.

After the four elements are characterized, a set of curves is constructed to portray the end-to-end link performance. These curves display the fully loaded performance and are equally suitable to show operational performance at normal light channel loading. The curves permit conversion of the

TEP Report # ______ DCA Link # ______ PMP Link # ______ Dated ______

Element		Item	Calculated Value	Link ____ A	B	____ A	B
Receiver		Noise Figure					
		IF Bandwidth					
		FM Threshold					
		Per Channel Deviation					
		Pre-emphasis					
		Frequency Slots					
		Fully Quieted					
Receiver and Transmitter		NPR (loop)					
		BINR (loop)					
Multiplex		NPR (loop)					
		BINR (loop)					
System		Number of Channels					
		Receive Signal Level					
		NPR (link)					
		BINR (link)					
		Channel Load Factor					
End to End Channel Performance		Baseband Loading					
		Idle Channel Noise (3 KHz)					
		Idle Channel Noise (C msg)					

Table 2 - 1

performance of the light loading to equavelent performance at the design full load point. Thus, all evaluations by management can be on a common base - performance that would be provided in a realistic hostilities charged environment - fully loaded.

If all data in the T.E.P. is not internally consistent, and much of it is not, it may be correctable using the self-check approach covered in the TEPA.

STEP 3 Data Analysis

Table 2-2, gives the equations for calculating the various required parameters. Portions of a specific T.E.P. report are used to illustrate the method of calculation and analysis. Chapter III is an example TEP Analysis, thus, those interested in applying the approach should read both chapters in parallel.

A. RF Carrier Determining Elements.

The sequence of elements outlined on the first paragraph of Chapter II, lists the RF related structure as the first item of interest. There is one action, however, that must precede the RF resolution. Although the receive signal level can be measured out-of-service a number of ways. It can be measured in-service at only one point that gives an absolute link measurement. For example, a measurement made at the transmitter is of relatively little link use since there are many pieces of wave guide, antenna hardware, filters, and alignment considerations, in addition to the propagation path that can adversely affect the signal. Thus, the presence of a proper transmit signal to the transmit wave guide is no guarantee of a correct receive signal at the receive end. Conversely, however, the presence of the proper signal at the receiver is proof of acceptability of the transmitter power and all intervening hardware and propagation matters. Thus, determining the RSL at the receiver is the theoretical valid and practical place to start any link analysis.

TEP Analysis Calculations

TABLE 2-2

I. Noise Threshold RSL (NT) = $-174 + 10 \log BW_{IF} + NF$ (in dbm)

II. FM Threshold RSL (FMT) $\doteq$ NT + 10 (in dbm)

III. FM Improvement (FMI) = $20 \log \frac{\text{per ch dev}}{f\ (\text{slot})} + 10 \log \frac{BW_{IF}}{3100}$ (db)

IV. Channel Noise at FMT (N_{FMT}) = $FMT - NF + 20 \log \frac{\text{per ch dev}}{f\ (\text{slot})} \pm P + 139$ (dbm)

V. Channel Noise at Ø RF Signal (Ø Sig N) = $-N_{FMT} + FMI + 1$ (dbm)

VI. Receive noise fully quieted = Ø Sig $N_{(slot)} - 70$ (dbm)

VII. Baseband loading 12 to 240 ch = $-1 + 4 \log N$
240 ch up = $-15 + 10 \log N$

VIII. Channel load factor = $-2 - 6 \log N$

NF = Receiver Noise Figure

BW_{IF} = Bandwidth of IF

f (slot) = frequency slot in baseband

P = pre-emphasis

N = number of radio channels

Per channel deviation is RMS

The normal way to measure the receive signal level is by use of the receiver calibrated AGC curve (automatic gain control) gathered as part of the receiver characterization. Thus, the approach to calculate, measure, and analyze the receiver is the first analysis step. Additional receiver analysis will be used later in the examination of the other elements of the link.

STEP 4 Receiver Quieting Curve

The receiver intercept points are extracted from the Table 2-2, calculations. The de-emphasis and FM Threshold can be extracted directly from the receiver quieting curve.

Figure 2-1, is a generic quieting curve with the four key intercept points identified. In the past, the FM threshold has been defined only by the RSL intercept point (point 1). On many receivers this threshold is difficult to locate precisely, and lends itself to considerable fudging. When the second intercept point (point 2) is added, the intersection of lines from these two points specifies the FM threshold and disparities are clearly visible. The quieting curve must start from the point where there is no discernable RF signal at the receiver input. This signal level is ascertained when a decrease in RSL gives no further increase in noise. (-115 dbm should be standard) This intercept point (3) is highly enlightening and presents information on the condition of the front end of the receiver and first stages of the IF - including the receiver noise figure. The spread between the low and high slot gives the receiver de-emphasis factor.

The quieting curve must be run to an RSL of at least -20 dbm or stronger. This is normally well past the point when the curve has flattened out and is called the fully quieted portion of the curve. A higher RSL does not produce any lower noise in a receiver, but may produce more. The

Key Intercept Points of a Quieting Curve

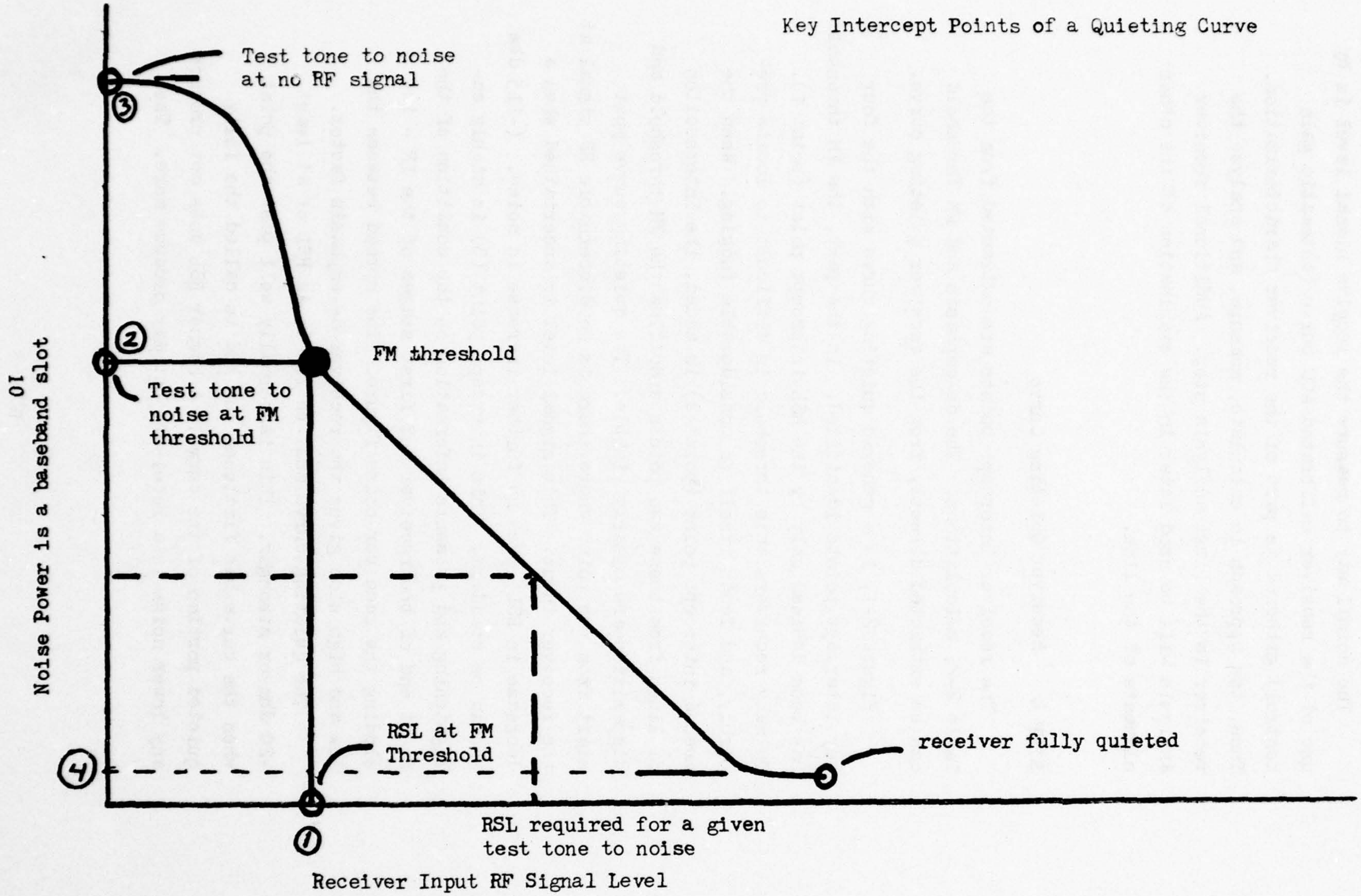


Fig 2 - 1

-20 dbm point, however, must be reached to assure that the receiver does not have poor overload characteristics, and does not introduce distortion noise. There are several DOD radios that normally display poorer performance at RSL's even slightly above 'normal' during ducting or when installed in a short link. Better grade radios evidence degradation in this portion of the quieting curve when maintenance is required in the IF stages.

These four intercept points, and the FM threshold defined by the intersection of lines thru points 1 & 2, fully specify a good receiver quieting curve. This analysis will normally plot only the mid-frequency slot. For a greater depth analysis, the identical approach is followed for the low and high baseband slots. In general, a 'low', mid, and a 'high' slot are included in T.E.P. measurements and thus are ideal for calculation and comparison.

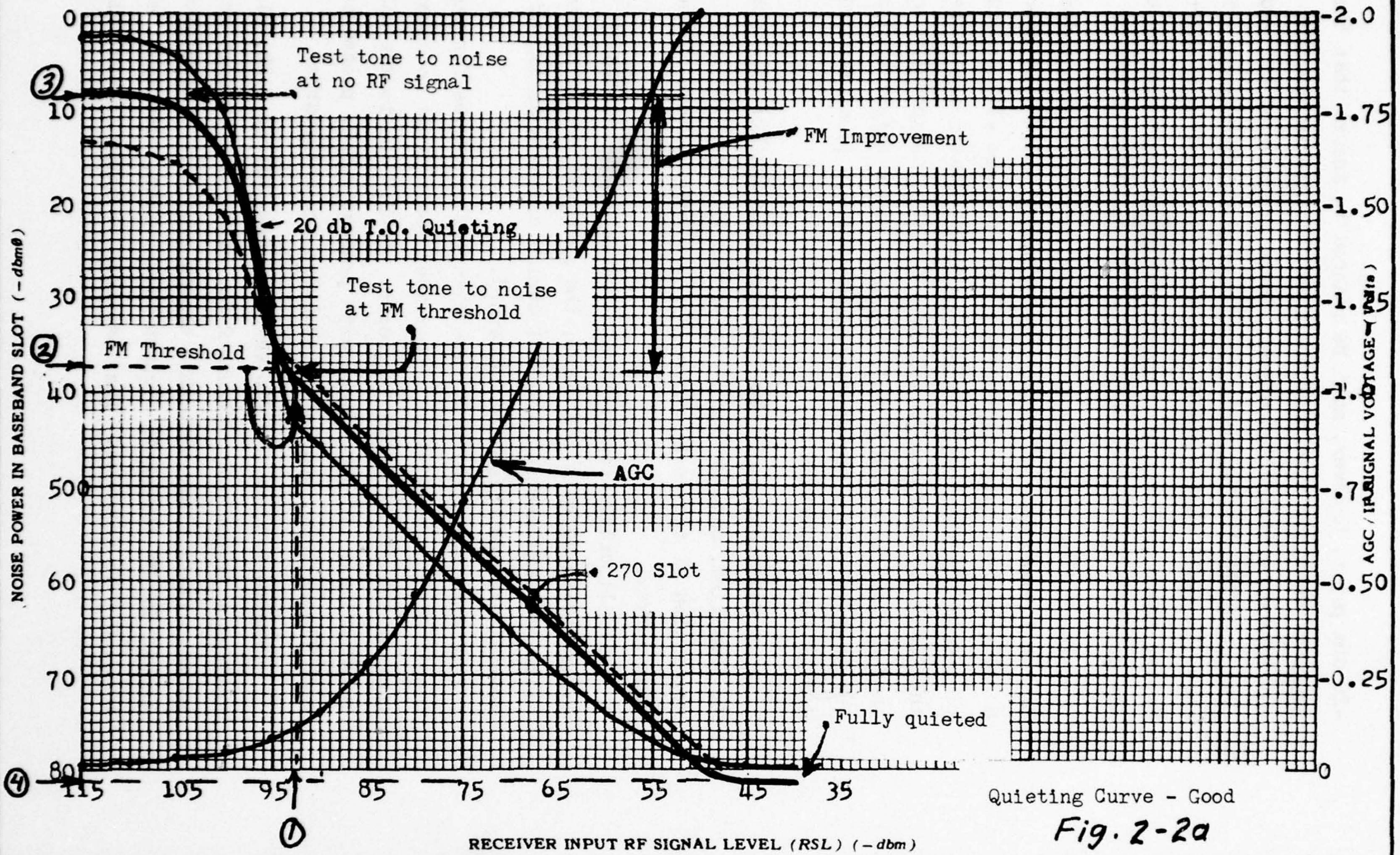
In addition, it is easy to determine whether de-emphasis is installed, and whether it is proper by observing the separation of the no RF signal #3, intercept points of the slot curves.

If all calculated intercept points are validated by the T.E.P. measured quieting curve, the receiver can be considered 'like new' and meeting original design criteria as far as sensitivity and noise are concerned.

Figure 2-2a, and 2-2b, are examples of curves for two identical type receivers. The reader can attempt to assess whether the FM threshold is proper. (-92.7 dbm is the calculated value). In accordance with present T.E.P. procedures, both Figure 2-2a, and 2-2b, receivers are acceptable.

Figure 2-3, is the 270 KHz slot from Figure 2-2b, plotted against a proper one, Figure 2-2a, with all intercept points shown. It is clear that this second receiver is defective even though the FM threshold appears about right. The front end is about 4.5 db degraded. The test tone to noise (often called

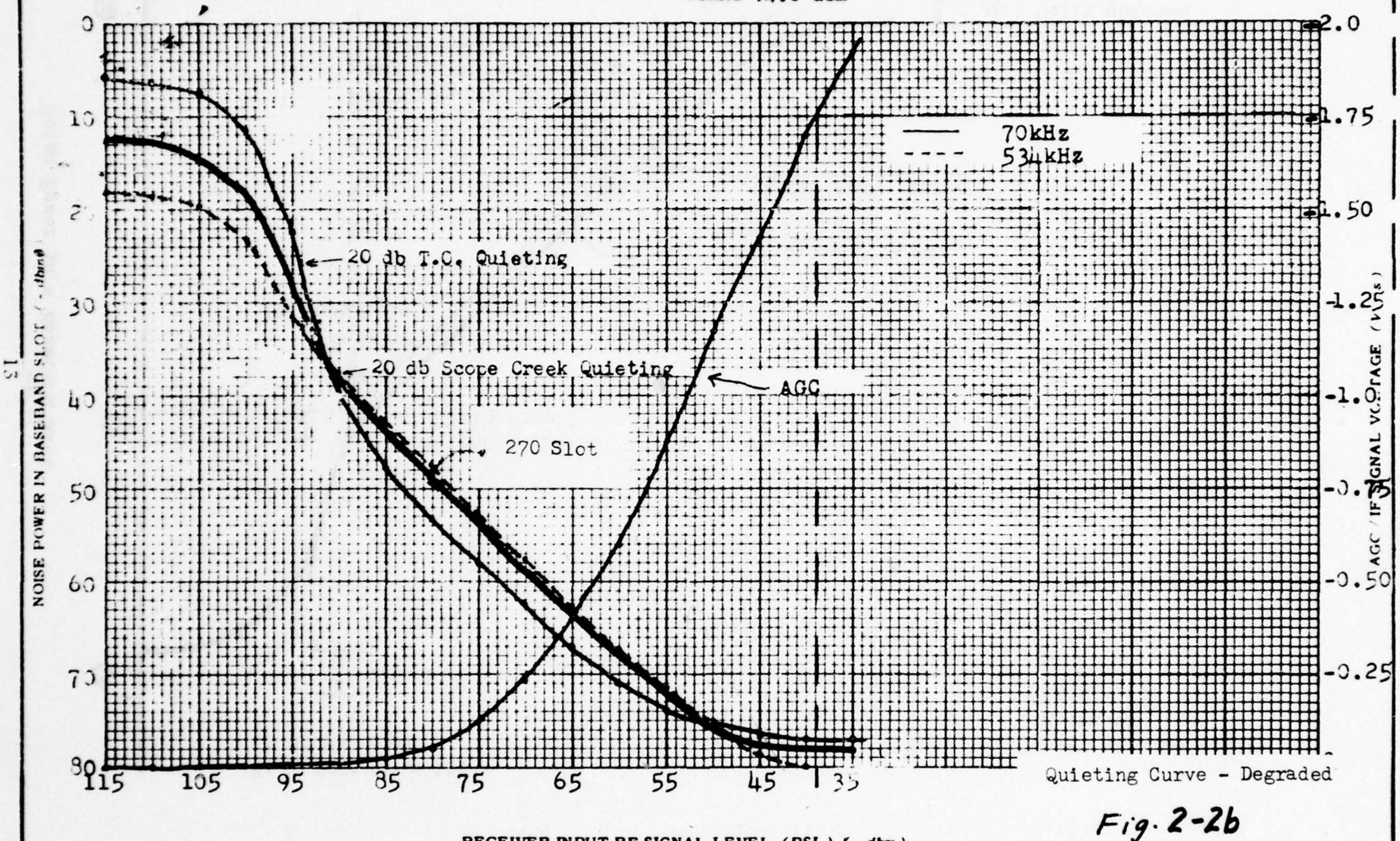
DATA SHEET B-9b: AGC & FM QUIETING CURVES				PAGE 3 OF 13 PAGES
REFERENCE Figure B-9c	EQUIPMENT Receiver No. 1	RECEIVE SIGNAL LEVEL REQUIRED FOR 20db QUIETING (From graph) 534 kHz 95.0 dbm 70 kHz 97.0 dbm	B/B SLOT WIDTH 3.1	UPPER B/B SLOT FREQUENCY 534



Quieting Curve - Good

Fig. 2-2a

DATA SHEET B-9b: AGC & FM QUIÉTING CURVES				PAGE 6 OF 13 PAGES
REFERENCE Figure B-9c	EQUIPMENT Receiver No. 4	RECEIVER SIGNAL LEVEL REQUIRED FOR 20db QUIETING (From graph) 534kHz 90.0 dbm 70kHz 94.0 dbm	B/B SLOT WIDTH 3.1 KHz	UPPER B/B SLOT FREQUENCY 534 KHz



Quieting Curve - Degraded

Fig. 2-2b

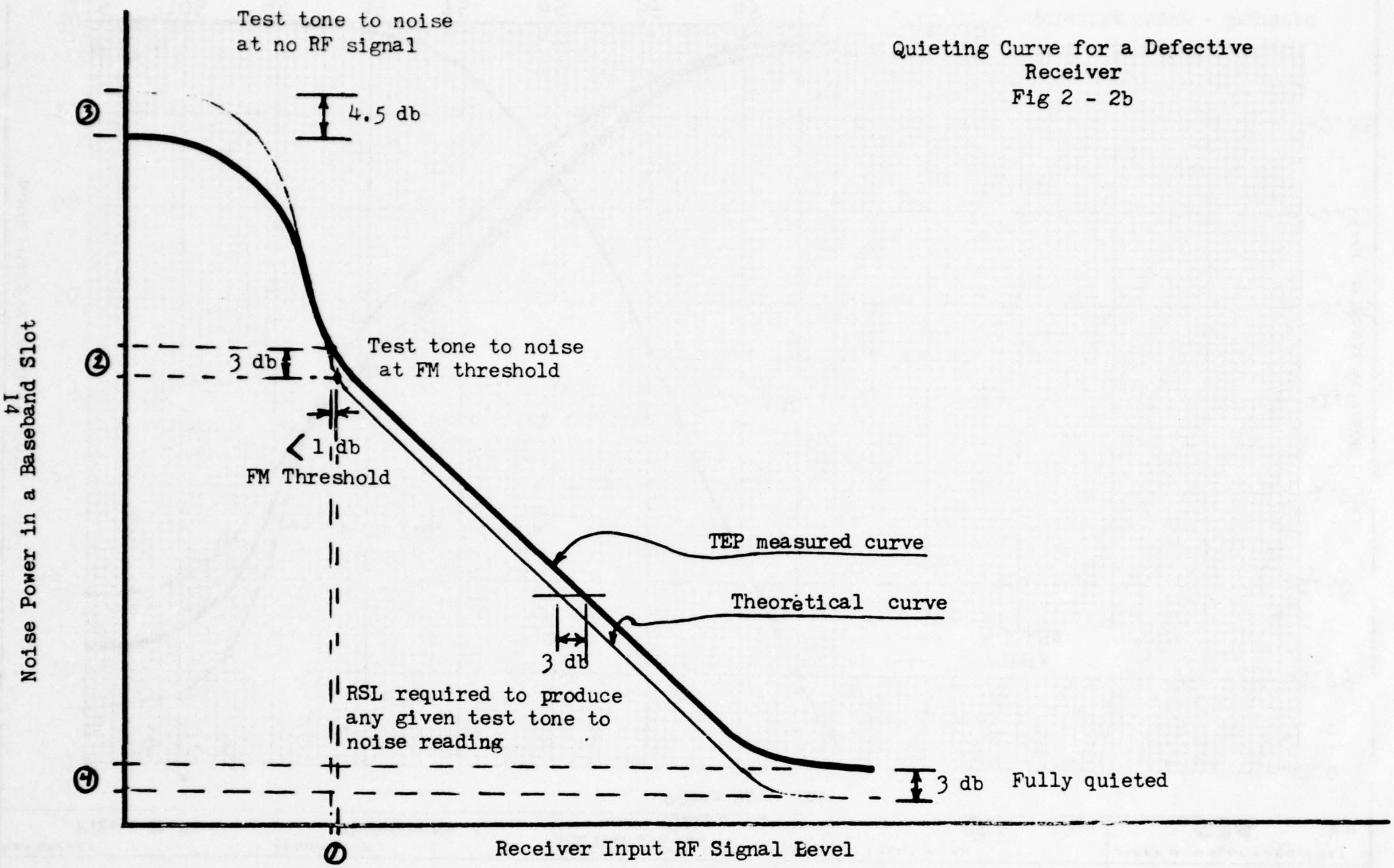

Quieting Curve for a Defective
Receiver
Fig 2 - 2b
Test tone to noise
at no RF signal
4.5 db
3
2
3 db
Test tone to noise
at FM threshold
< 1 db
FM Threshold
TEP measured curve
Theoretical curve
3 db
RSL required to produce
any given test tone to
noise reading
4
3 db
Fully quieted
1
Noise Power in a Baseband Slot
Receiver Input RF Signal Level

Fig 2 - 3

signal to noise) ratio at FM threshold and along the entire linear portion of the curve is 3 db too noisy. (That is, it takes 3 db more RSL for a given channel noise and 3 db fade margin is lost). The fully quieted portion is 3 to 4 db noisier than the Figure 2-2a, good receiver although both meet minimum theoretical calculations.

Clearly, the receiver in Figure 2-2b, needs work - but the present T.E.P. team and the report procedures failed to note this degradation.

STEP 5 Receive Signal Level Determination

The original objective of first analyzing the receiver characterization, was to assess the non-fade median receive signal level. On Figure 2-2a and 2-2b, there appears an automatic gain control (AGC) curve gathered simultaneously with the balance of the receiver quieting information. This is known as automatic volumn control in commercial and high fidelity products. The AGC curve, if it is correctly calibrated, can be used to determine the RSL accurately even though the receiver itself is degraded. For example, in Figure 2-2b, if the AGC voltage measures to be -1.75 volts, this voltage indicates correctly a -39 dbm RSL.

Thus, after the receiver is characterized and the AGC curve plotted, the matter originally desired can be addressed. Does the RF related structure as engineered and installed, provide the RSL that theory would prognosticate? The TEP measurements directly verify the T.E.P. path predicted values.

The T.E.P. measurements may be measured directly or extracted from a strip chart recorded AGC value calibrated in RSL. Disparities between calculated and measured values are readily apparent either way.

If the transmitter power is proper and the received signal level as determined by the receive AGC readoff is as calculated, then clearly no gross attenuation or antenna mal-alignment is present. A proper receive signal level validates at least acceptable antenna configuration alignment and predicted propagation losses, no disruptive ground reflections, and rules out major wave guide problems or cross-polarization. There may be weather-induced problems, but T.E.P. normally measures the RSL during good weather to avoid those imponderables.

The RSL parameter does not prove the absence of non-linearities or phase delays in the RF structure. However, after the receive signal strength is measured to agree with the calculated value, indirect parameters are used to assess other possible degradations in the RF structure. These will be described under the NPR tests.

Simple one frequency VSWR (Voltage Standing Wave Ratio) measurements are possible, and in many cases are helpful in illuminating a problem, or in isolating an already recognized faulty RF structure, but are far from adequate for full assessment. Completely valid swept frequency VSWR tests are normally performed only by special maintenance teams and only after a clear and unambiguous indication of a major RF structure problem - if such a proper characterization is ever performed at all.

If the predicted value and measured values are within $\pm$ 1 db, validation is assumed to be achieved. If the variance is $\pm$ 3 db, there is some significant problem that should be examined further by the T.E.P. team. If the disagreement exceeds $\pm$ 3 db, there is a major measurement error or RF structure difficulty that must be analyzed, dissected by further measurements and corrected by the T.E.P. team, if possible, or clearly described in the report for management attention.

If, as is frequent, the team departs the site with the receive signal level problem unresolved, the report should be classed as 'incomplete' until the disparity has been resolved, and not submitted to DCA. Only by such care can the decision be made as to whether a link engineering error is present, an installation problem remains, antenna realignment or other maintenence action is required, or whether some poor operations practice such as severe baseband overload exists.

Figure 2-4, shows a type of information formerly gathered during T.E.P. This link configuration is valuable and may be mandatory information if RSL, interference, wave-guide loss factors, etc., are to be analyzed. This data is not presently required and should be reinstated in the T.E.P. report format.

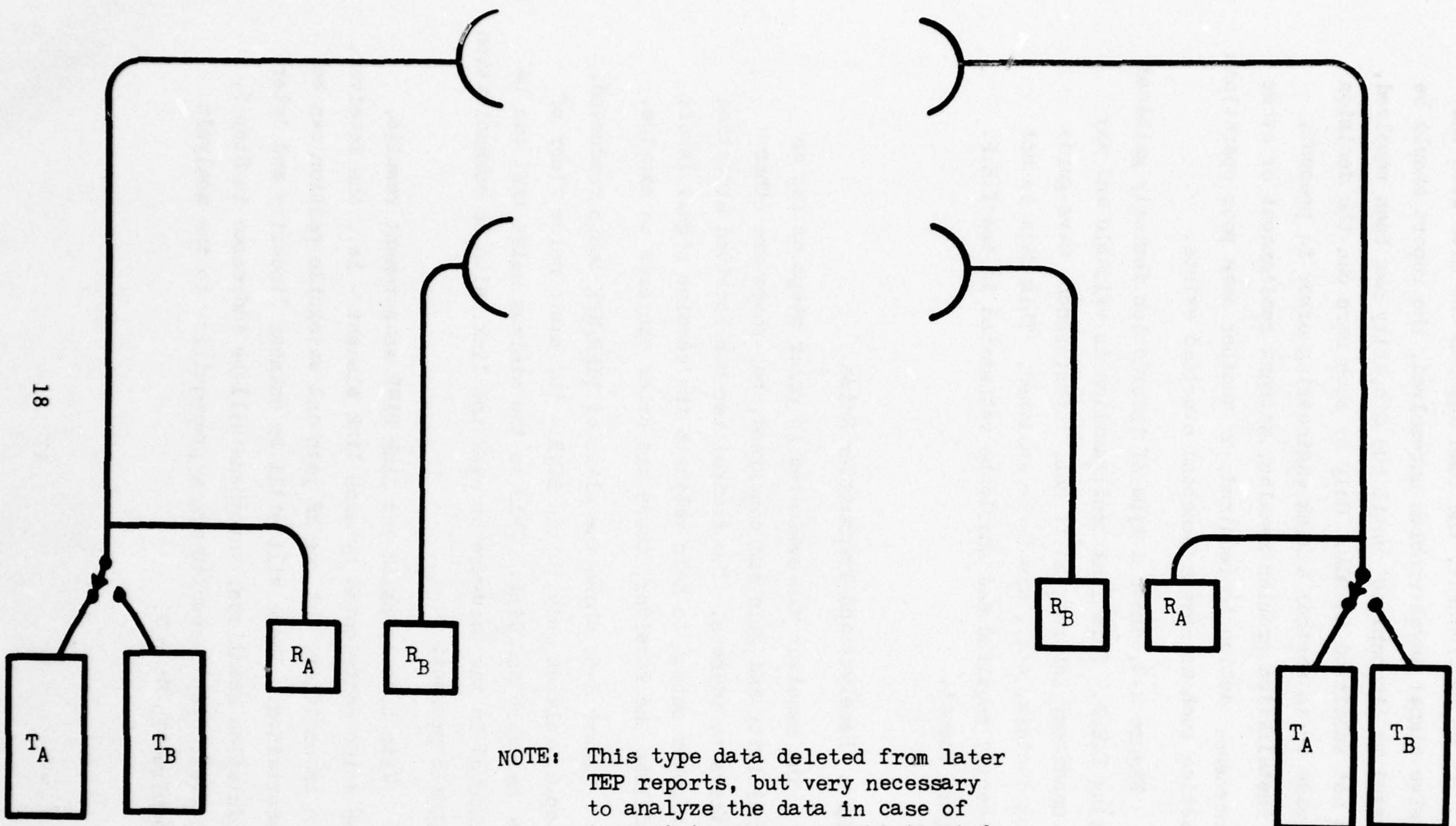
STEP 6 Receiver and Transmitter Noise

The receiver was evaluated in prior steps as far as sensitivity and gain are concerned, but there are other matters to address. The transmitter has received attention for power output to help validate the receive signal level; and like the receiver, there are other concerns to examine.

Figure 2-5, shows the class of BINR/NPR tests conducted. Step 6, relates only to the BINR - the basic noise floor of the hardware and link. This is the minimum noise that can be measured in the hardware or over the link, with no communication signals present.

With both loopback and link BINR measurement results, the noise contributed by each link element - ie., the receiver, the transmitter, and the RF path and waveguide portion, can be ascertained. There will still be unknown linearity and intermodulation questions, but these will be addressed in Step 7. However, Step 6 results are a prerequisite to the analysis required in Step 7.

LINK HARDWARE CONFIGURATION



NOTE: This type data deleted from later TEP reports, but very necessary to analyze the data in case of inconsistencies or sophisticated problems.

Fig. 2 - 4

The T.E.P. tests measure the BINR on an integrated transmitter and receiver as a pair. It would be academically satisfying and technically desirable if the transmitter and receiver could be directly measured separately and each evaluated on its own merits. Unfortunately, there is no simple method to assess the complete noise and linearity performance of either the transmitter or receiver in isolation, without special test equipment, not generally available to the T.E.P. teams.

A universally achievable BINR figure, although not stated in the path calculations, should be at least 60 db (or 5 db quieter than the NPR).

A microwave link normally operates in the fully quieted portion of the quieting curve. The measured basic noise floor BINR - of the receiver can be extracted from the receiver quieting curve, and compared directly with the calculated values from Table 2-2.

In a properly designed and maintained radio, the transmitter BINR is 2 to 5 db quieter than the receiver. Thus, the appropriate transmitter noise can be surmised from the receiver fully quieted noise minus about 4 db. The noise of the transmitter is validated from the in-station BINR loop tests. If the joint T-R BINR is 60 db or quieter, there is no problem operationally. If it is noisier, then numerical comparison with the calculated values is required.

The BINR test is run as an in-station loop, and may be required in several combinations. Transmitters A and B must be measured with both receivers A and B. Thus, four combinations are possible:

a. $T_A - R_A$

b. $T_A - R_B$

c. $T_B - R_A$

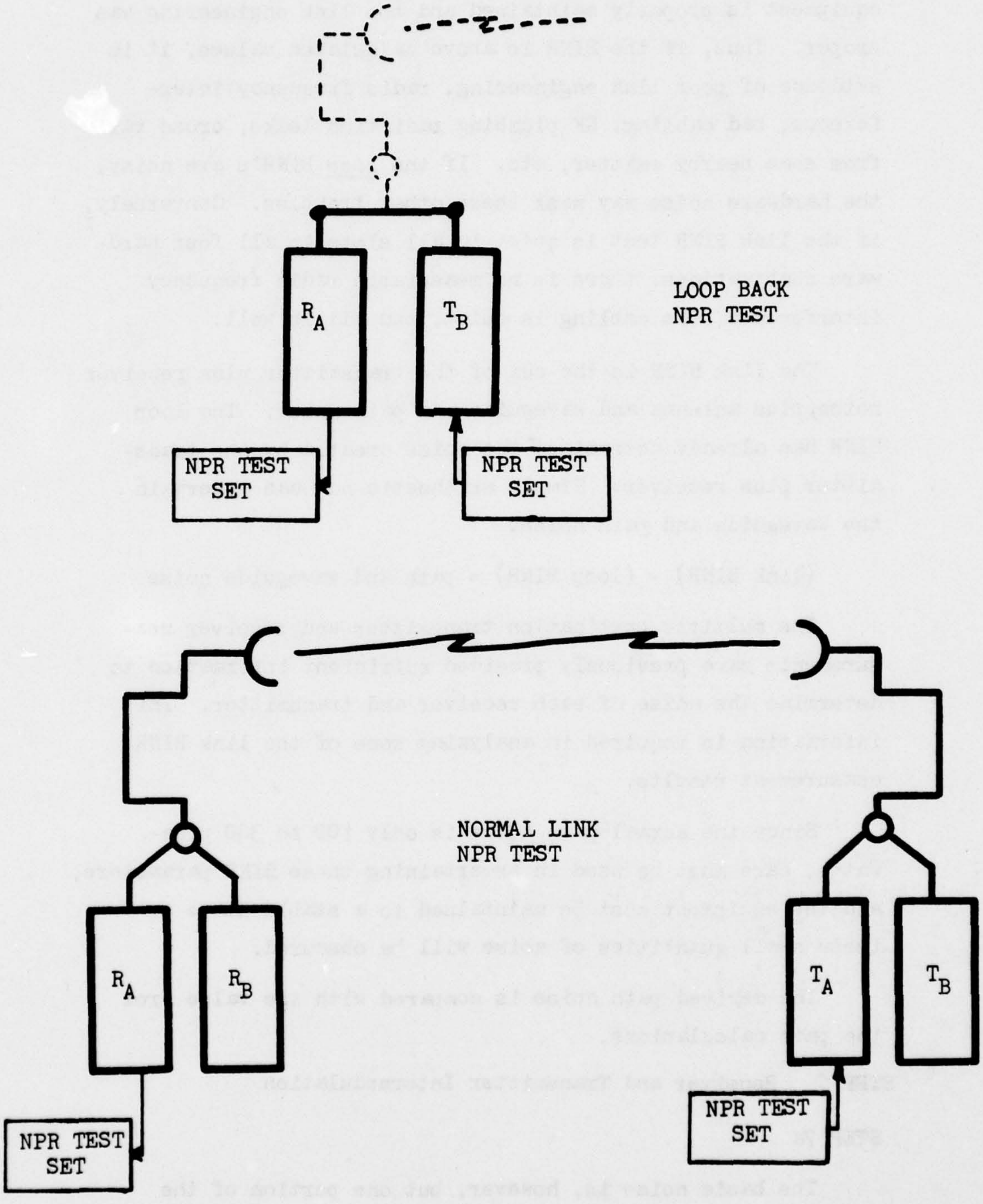
d. $T_B - R_B$

This apparently trivial combination point is expanded here because it is not a simple issue. From a noise standpoint, test a and test d, have assessed the noise of all four components. If both T-R pairs are quiet there is no further problem. If $T_B - R_B$ only is noisy, additional tests are needed. Since R_A was quiet in test a, if $T_B - R_A$ is quiet, then R_B is noisy. If $T_B - R_A$ is still noisy, T_B is obviously noisy. However, the status of R_B is still in question. Thus $T_A - R_B$ must be run to be sure that R_B is not degraded, since T_B noise could have masked the lesser, but still excessive R_B noise. The analysis may even be simpler since proper quieting curves will already have validated acceptable receivers, and any noisy combination clearly identifies a poor transmitter, <u>or a noisy interconnect and cable structure</u>. On occassions, all baseband slots may have to be analyzed separately, if the noise is not flat across the baseband.

Assessing noise is relatively easy and in most cases such noise is quickly corrected by replacement of degraded electronic components. The selective voltmeter is used as a frequency selective stethoscope to probe through the equipment until the noise is located. Where such repair actions fail, the possibility of a poor installation or bad installation engineering must be explored and the problem isolated. Cables can be measured if there are indications of problems in these interconnects. Bad connectors are sometimes hard to find, but are capable of isolation by really skilled personnel.

The second part of Step 6, relates to the link BINR. Figure 2-5, illustrates the considerable difference between the loopback and link configurations.

BINR data in <u>link</u> provides considerable information concerning the cabling, wave guide condition, and RF interference and cross talk. The link BINR data basically portrays the propagation noise, and the T-R equipment noise. In the



NOISE POWER RATIO (NPR) TEST
BASIC INTRINSIC NOISE RATIO (BINR) TEST

Fig 2 - 5

case of a microwave link, neither of these is large - if the equipment is properly maintained and the link engineering was proper. Thus, if the BINR is above calculated values, it is evidence of poor link engineering, radio frequency interference, bad cabling, RF plumbing radiation leaks, cross talk from some nearby emitter, etc. If the loop BINR's are noisy, the hardware noise may mask these other troubles. Conversely, if the link BINR test is quiet in all slots in all four hardware combinations, there is no measurable radio frequency interference, the cabling is quiet, and all is well.

The link BINR is the sum of the transmitter plus receiver noise, plus antenna and waveguide and path noise. The loop BINR has already determined the noise created by the transmitter plus receiver. Simple arithmetic now can ascertain the waveguide and path noise.

(link BINR) - (loop BINR) = path and waveguide noise

The multiple combination transmitter and receiver measurements have previously provided sufficient information to determine the noise of each receiver and transmitter. This information is required in analyzing some of the link BINR measurement results.

Since the normal path noise is only 100 to 300 picawatts, care must be used in ascertaining these BINR parameters, and the equipment must be maintained to a stable state or these small quantities of noise will be obscured.

The derived path noise is compared with the value from the path calculations.

STEP 7 Receiver and Transmitter Intermodulation

STEP 7a

The basic noise is, however, but one portion of the necessary criteria for an acceptable T-R combination. The other major evaluation criteria necessary is the linearity.

The linearity is measured during the NPR test - the non-linearity products on a good T-R pair should be 55^{+}db down. The receiver IF, discriminator and the transmitter IF (if one is present), klystron or traveling wave tube amplifiers are prime causes of these non-linearities.

The mechanical process of measuring intermodulation distortion is absolutely straightforward, and errors are rarely made. The equipment condition and the analysis and interpretation of the NPR test results, however, are not so straightforward. For example, assume that the T_A - R_A NPR measures 55 db. This can mean that the pair is 'like new' and distortion is low, or it can mean that the receiver has high non-linearity but that the transmitter has been adjusted to an equally high non-linearity but of opposite sense and the two distortions compensate. There are two approaches to reconcile this seeming imponderable.

The first way is to use a test instrument such as a Link Analyzer to measure a receiver and align to high linearity of 58 db or better, using the Link Analyzer absolutely linear source. (Thus the T-R combination can equal 55 db with a transmitter also equal to 58 db NPR).

This linear receiver then can be tested with the T_A and T_B. NPR's of 55 db now are meaningful, and compensation is not concerned. This Link Analyzer method requires the addition of another test instrument for the T.E.P. teams. This clearly is the most desirable technical solution.

The second approach is to test all combinations of transmitters and receivers as discussed above in the BINR discussion. If each transmitter gives measured NPR values of 55 db or higher with either receiver, there is little possibility of matching but opposite non-linearities. The tendency of many T.E.P. teams to optimize T-R pairs by in-loop NPR's, is both wasted time and normally even further degrades the link per-

formance. In-station loop NPR's in excess of 55, always caution of compensation, and warn of poor link linearity. If the four combinations of T-R NPR tests are acceptable, there is no problem. If one or more tests are degraded, there is obviously a problem that must be resolved.

There are many tests called for in the present T.E.P. procedures that are helpful in isolating problems to the troublesome transmitter or receiver. These tests include:

a. IF bandwidth of the transmitter and receiver - too narrow bandwidth causes IM.

b. Transmitter deviation linearity - if measured.

c. Receiver discriminator curve - non-linear curve causes IM.

Much too little attention is paid to the discrimination curve. A typical curve that passes T.E.P. examination will still add 2 - 5 db of distortion, to the T-R total. The standard oscilloscope curve is useless except for very gross determinations. The point by point plot is often only approximate.

The loop NPR tests are sometimes done only in IF loop and thus bypass a major source of distortion - the transmitter output stage. IF loop NPR values in the 60's are normal and are not very informative except for fault isolation. A turn around mixer is required for a valid NPR test if the receiver and transmitter cannot be placed on a common frequency. The in-station loop NPR test integrates all of the receiver and transmitter elements and provides an operational performance figure that is both complete and valid, but only if done correctly.

STEP 7b

There is a second series of NPR tests conducted as part of the T.E.P. measurement program. These tests are conducted over the radio path. All of the admonitions about compensating non-linearities also hold equally for these link tests.

Thus, four combinations of transmitters and receivers must be evaluated to assure linearity. If the link analyzer has been employed, one linear pair can validate the path suitability and associated waveguide and antennae structure. The remaining waveguide - antenna will still be unknown, so at least one other pair must be tested.

The normal industrial and DOD approach is to measure the NPR (and BINR) for a number of frequency slots across the baseband. A frequency at the low, mid, and top frequency of the baseband is usual. This NPR data is tabulated in the T.E.P. report.

Previously, T.E.P. analysis consisted of comparing each frequency slot NPR with 55. If it were somewhere near, 47 db or better, no concern was expressed.

However, the analysis of a link must entail much more than a superficial examination of the NPR numbers, and administratively noting any deviation from the design specs. The operational impact is the key criteria. Note: a prerequisite to a meaningful link NPR test is the successful maintenance of the T-R pairs, so that all combinations have quiet BINR readings. If the hardware is noisy, the analysis of the link NPR information is difficult and may be impossible. In many links, the basic noise is so high that it swamps the intermodulation noise. This type data appears: $\frac{47}{51}$, $\frac{48}{48}$, $\frac{47}{47}$.

The low slot has a measured BINR of 51 db. The NPR measures 47 db - although it actually is -49 db. (49 db + 51 db = 47 db). In the mid and high slots, the BINR is so high that the contribution of the intermodulation is not measurable - so the NPR must be at least 5 to 6 db lower. Thus, the true NPR in this example would be approximately 49, 54^+, 53^+. These values are within relatively simple repair range of the proper 55 db, but that is of little comfort to the user, because his channels will be basic noise limited.

Reference Figure 2-5. The link NPR test differs from the loop NPR by the inclusion of two classes of problems, neither of which should have measurable effects in a well designed link. These are the waveguide and antenna, and the propagation path. Consequently, the link NPR numbers should approximate the loop NPR measurement results. If the waveguide structure has mismatches, the reflected signal will appear as noise, and is called echo distortion. When some hill, building, or other obstruction introduces a reflected signal to compete with the normal receive signal, the effect is called multipath and also introduces noise. If a strong signal along the path can enter the antenna, waveguide structure, transmitter or receiver, or the baseband cables, noise or perhaps discrete signals appear. The source of these spurious signals is most often a local broadcast transmitter that enters via the baseband cables. The signals may be from a local microwave transmitter, including those colocated at the site being measured or sharing the same hilltop. A high power source, such as a radar, may produce signals that enter the link at almost any point, including the power supply.

In the absence of any of these disturbing effects, and when the transmitter and receiver are linear, the link NPR tests will measure 55^{+}db. If the NPR measurements are degraded;

a. the equipment intermodulation is excessive.

b. the path introduces multipath.

c. the waveguide structure is defective.

d. there are spurious signals entering the link.

The NPR measurements do not always unambiguously disclose the cause of the difficulty, but by comparing the requisite four combination T-R pair measurements, by examining the data in logical groupings and in context with the physical layout shown in Figure 2-4, the source and likely entry point can normally be derived. No T.E.P. report can be classed as

complete until at least two combination pairs have achieved 55 db NPR. The two combinations must comprise one transmitter and two receivers, or two transmitters and one receiver to preclude any compensation effects.

The reverse, however, is absolutely illuminating. 55 db NPR measurements on all T-R pairs is proof that the transmitters, receivers, waveguide structure and path, all are linear and capable of quality communication - a full and valid engineering validation of these basic link elements.

4. NPR vs Baseband Loading

The baseband loading versus NPR curve is now specified as a requirement for all T.E.P. characterizations.

Figure 2-6 is an example of an NPR vs baseband loading curve on good equipment - an FM 8000. This class hardware is used later in this report for the Chapter III example link analysis, Bann - Langerkopf, Germany.

The elements of interest in this curve are simple.

a. The shape of the curves for all baseband slots should be the same.

b. The curves should all peak at about 55 db and at CCIR (or other design) loading.

c. The slope of the curves at points below CCIR loading (lightly loaded) should be exactly -1 db of NPR per -1 db of loading.

d. The slope of the curve at points more heavily loaded than CCIR should be approximately 2 to 3 db per db of baseband loading.

e. The breadth of the curves above 50 db NPR should be at least 10 db wide.

The NPR vs baseband loading curve can be run in loop or over the link, but should be conducted only after a successful NPR test -55 db. The routine gathering of this data on degraded hardware is useless. NPR/baseband loading tests

FM 8000

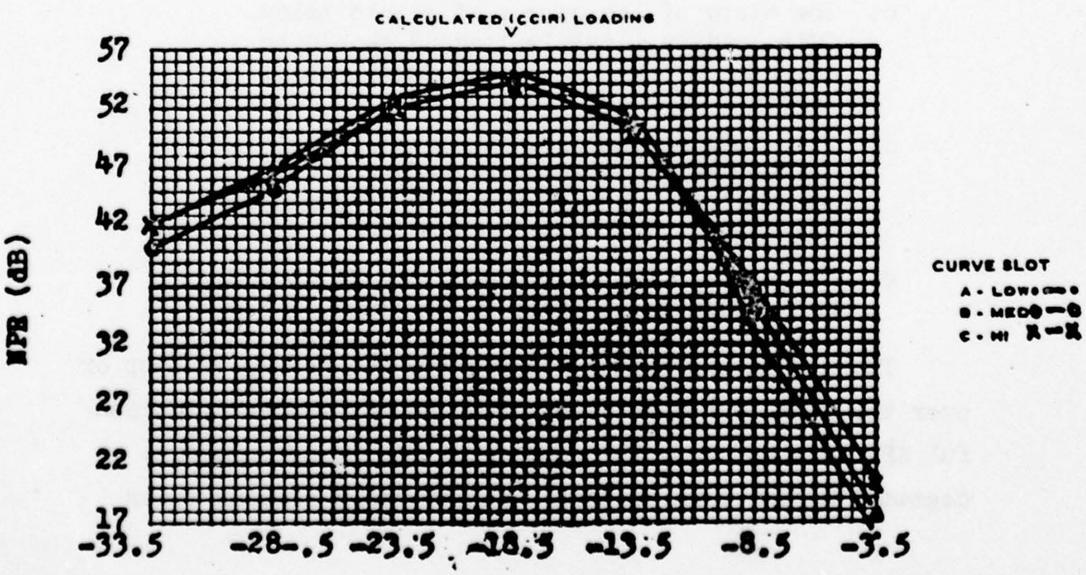
DATA SHEET	FACILITY TESTED	DATE
M-14A-2: TRANSMITTER – RECEIVER NOISE POWER RATIO (NPR) – RADIO LOOP BASEBAND LOADING CURVE	Muhl, Germany	18 Apr 73
	DISTANT FACILITY	INITIALS
	Bitburg, Germany	LCW

CCIR BASEBAND LOADING LEVEL			BASEBAND TEST POINT LEVELS	
CALCULATED	XMTR TEST POINT	RCVR TEST POINT	TRANSMITTER	RECEIVER
+7.5 dBm0	-18.5 dBm	+10.5 dBm	-26 dBm	+3 dBm

SLOT FREQUENCIES			BASEBAND LIMIT FILTERS	
LOWER	CENTER	UPPER	HIGH PASS	LOW PASS
70 KHz	270 KHz	534 KHz	12 KHz	552 KHz

TRANSMITTER NO.	RECEIVER NO.
☐ DISTANT ☒ LOCAL	☐ DISTANT ☒ LOCAL

ACTUAL XMIT LEVEL		RSL (-dBm)	RECEIVE BASEBAND LEVEL (dBm)	NOISE POWER RATIO			BASIC NOISE RATIO		
DEVIATION FROM CCIR	BASEBAND INPUT (-dBm)			LOWER SLOT (dB)	CENTER SLOT (dB)	UPPER SLOT (dB)	LOWER SLOT (dB)	CENTER SLOT (dB)	UPPER SLOT (dB)
-15 dB	33.5		-0.3	42	40	42			
-10 dB	28.5		+2.5	47	45	46			
- 5 dB	23.5		+6.0	53	51	51			
CCIR	18.5	45	+10.5	55	54	54	60	60	61
+ 5 dB	13.5		+15.5	51	50	50			
+10 dB	8.5		+20.5	33	35	36			
+15 dB	3.5		+24.5	15	17	20			



BASEBAND LOADING CURVE (dBm)

Fig 2 - 6

should be terminated unless three combinations can meet 55 db, or the T-R pair has been assured linear by use of the link analyzer. A key point again, is that prior quiet BINR tests are mandatory.

The few T.E.P. teams who can achieve 55 db NPR measurements over the link in all combinations, can provide these NPR vs baseband loading curves over the link. There is a very good reason to have a few of these curves properly gathered on each class of radio - ie. Collins 600 ch., Siemens 132 ch., etc. This curve is used to create a valuable composite curve that relates idle channel noise in any lightly loaded condition to that idle channel noise that would result if the link were to be loaded to full design capacity - an Equivalent Fully loaded idle channel noise derivation chart.

The use of this curve will be covered in the audio to audio link tests. The derivation, and scientific basis for this composite curve is explained in the appendix.

STEP 8 Multiplex

The multiplex equipment is the conversion box between the audio channels and the baseband input to the radio. As such, it is always serial on all voice channels.

There are 15 tests - two are optional - run by the T.E.P. teams related to multiplex performance. ALL of these tests are interesting and informative to an O&M Agency. Only a few are of direct relevance to an engineering agency. The bulk of the parameters measured are generally time independent and so do not degrade measurably over extended periods. Thus, 'like new' measurements made during test and acceptance remain constant and can be considered 'normal' real life field data. (One of the few items in communications that does remain constant). Channel impedance, channel frequency response, channel envelope delay, and phase jitter, are routinely constant with time, and can be used as fixed engineering data with little concern.

Perhaps, on a seven year cycle all tests should be run to pick up those very few changes that may have escaped routine maintenance.

The tests of engineering interest that do not remain fixed, include channel intermodulation levels, idle channel noise, and frequency translation. These tests, however, are directly related to the channel factors visible to the user, and are the prime ones to disclose those parameters of the multiplex that do deteriorate. Thus, these should remain in the T.E.P. test series. The other should receive selective spot checks.

The two key tests are the ones that measure the Mux BINR and NPR, and these are the ones most needed.

It is possible to loop back the multiplex equipment at baseband and perform a series of tests. The test of most interest is very similar to and conducted much like the radio loop NPR/BINR measurement. The BINR test is usually accomplished by the T.E.P. The NPR test is easy but very tedious and requires more test equipment, many patch cards and considerable time - as a result it is normally neglected by the T.E.P. teams.

The loopback BINR data is still very useful in detecting hardware problems with the basic equipment if the test is run properly. The transmit and receive portions of that multiplex are looped in station. If the loop is done at the ends of the baseband cables, using whatever amplifiers are required to match levels, the loopback BINR will detect most signals and noise entering the baseband or mux structure. (Most, rather than all, because some signals can fall between voice channels and these will be attenuated by the voice channel filters, although intermodulation cross products may be evident). The measurements of noise should be made at the regular equal level jack field, so that all crosstalk, fluorescent light buzz, power line hum, clicks, etc., picked up by the audio cabling is also assessed by the BINR (idle channel noise) measurements.

Analysis of these noises - equipment, baseband cables, and audio cables - permit identification of excessive idle channel noise in a channel, a group, a super group or all across the entire baseband. All proper multiplex equipment should have BINR idle channel noise of -70 dbm CØ or quieter. Newer solid state mux will meet -70 dmbØ or quieter in the idle state. There will be a few channels that may be a few db noisier. More noise is evidence of a bad channel or larger subelement of the multiplex.

There are a series of spot channel tests such as harmonic distortion, crosstalk, frequency response, etc., but these evaluate only the hardware aspects of a few channels, and do not view the multiplex as a fully loaded totality. These also relate to site maintenance and have little relevance to broad engineering matters. There will be data of interest to the traffic people concerning adverse characteristics in particular channels such as channel #2 in every group in the UCC 4 always has a 70 Hz tone present, but these type assessments should be conducted during test and acceptance.

Thus, at the end of the normal T.E.P. multiplex tests, the specific definitive overall performance of the mux is not known, since the mux loaded noise (NPR) is rarely measured. There is little likelyhood that the added weight and cost of test equipment, the added patch cords unique to the particular mux or jack field, or the time will be afforded. Thus, the mux like the other three major subelements must be tested in some indirect way. This indirect approach will be covered at the end of this chapter in the end-to-end audio link tests.

In a few cases the engineers have had the extra competence and added initiative to run the mux NPR test. As a result, the specifics of the noise vs. loading curve of the full multiplex are known, in the case of the VZ-12. This mux NPR curve is displayed in the appendix.

STEP 9 Interconnect Cables

The interface cables and connectors are easy to measure, but normally are not addressed, since the T.E.P. does not require it. The audio cables probably need not be measured separately. They should be evaluated in association with individual voice channels, and be checked during the loopback of the multiplex when test tone level and idle channel noise is measured and also during the audio to audio link tests. The T.E.P. teams normally clearly identify the noisy channels. As far as DCA engineering is concerned, this may be all that is required, but the O & M agencies still have open questions as to the source of the noise - multiplex or cabling - and so do the DOD users.

The baseband cables have been a source of trouble repeatedly surfaced by Scope Creek since 1968. The solution most often applied by the O & M agencies in the extremely noisy cases, was to reground the cable and by various arts to balance the circulating currents. These approaches are temporary fixes at best, and often do not correct fully the problem. The standard 'excuse' given for this failure is poor station ground - but it is normally poor engineering design compounded by poor installation. To isolate problems, the baseband cables must be terminated at both ends and measured with a selective voltmeter to pinpoint noise or tones causing troubles. The cables also must be connected to the radio and remeasured and then connected to both the radio and multiplex and remeasured a third time. It is clear, from experience, that the DCA standard 'shielded coaxial' cable is not a satisfactory interconnect structure in many sites in Europe or in the Pacific. Double shielded balanced twisted pairs properly installed would solve the noisy cable problems. This solution is used in the Pacific and in Europe by the better radio manufacturers for noisy sites.

Thus, assessment of the cable and connector subelement, as in the previous three, less than a full job is presently accomplished, but this incomplete assessment can be compensated in the most important cases by proper baseband cable measurement, and by a multiplex loopback conducted from the equal level board.

The correction of all baseband cable problems awaits the issuance of a realistic baseband cable standard by DCA, and by the direction to retro-fit many links.

STEP 10 End-to End Channel Performance

All previous tests examined some bounded portion of the link under test. Each portion was measured to understand that element performance, and to validate key matters 'assumed' in the path calculations. The user is not interested in any such sub-element performance, and the engineer who designed the link should be predominantly interested in the total integrated performance of the link. (The user is really interested in considerably more, but certainly is not concerned in the least with less than the full link audio to audio.

There are two key link parameters that approximate user satisfaction - idle channel noise is clearly the most important. A second important parameter is impulse noise. Neither idle channel nor impulse noise can be assessed in any meaningful manner other than an end to end channel performance test.

There are several other parameters of interest to users. Phase jitter is of interest to data users and frequency offset is important to other customers - although they do not know it. These parameters are determined by the multiplex. These mux performance criteria were determined earlier during the mux test.

If enough of the hardware measures at or very near specs, then the final proof test is possible with high accuracy. Further, this serial linkage of the hardware is made using the

normal operational cable and interconnect structure. The RF waveguide structure to the antennae and the antennae was measured indirectly during link NPR tests. The baseband cables were partially measured during the mux tests, but normally only one of the two cables is used so a question may still be open. The audio cables are not measured directly in some cases, so their condition may be an unknown - unless assessed during the mux test.

The end-to-end serial configuration of all elements, is the condition assumed in the path calculations. Thus, the end-to-end channel performance should be identical to that derived by the path calculations - the measured idle channel noise should equal the calculated idle channel noise. This very basic comparison, is highly informative. Unfortunately, such direct correlation is possible only if the baseband loading is at the design level assumed in the path calculations. Nearly all links are 4 to 10 db underloaded and the idle channel noise should - and normally is - quieter than it would be if the link were fully loaded. Since no T.E.P. test adds synthetic loading to that already imposed by normal users, the link idle channel noise measurements are presently incomplete. If the link is lighly loaded and the channels are noisier than calculated, it always denotes a highly degraded link (assuming that the link was correctly engineered).

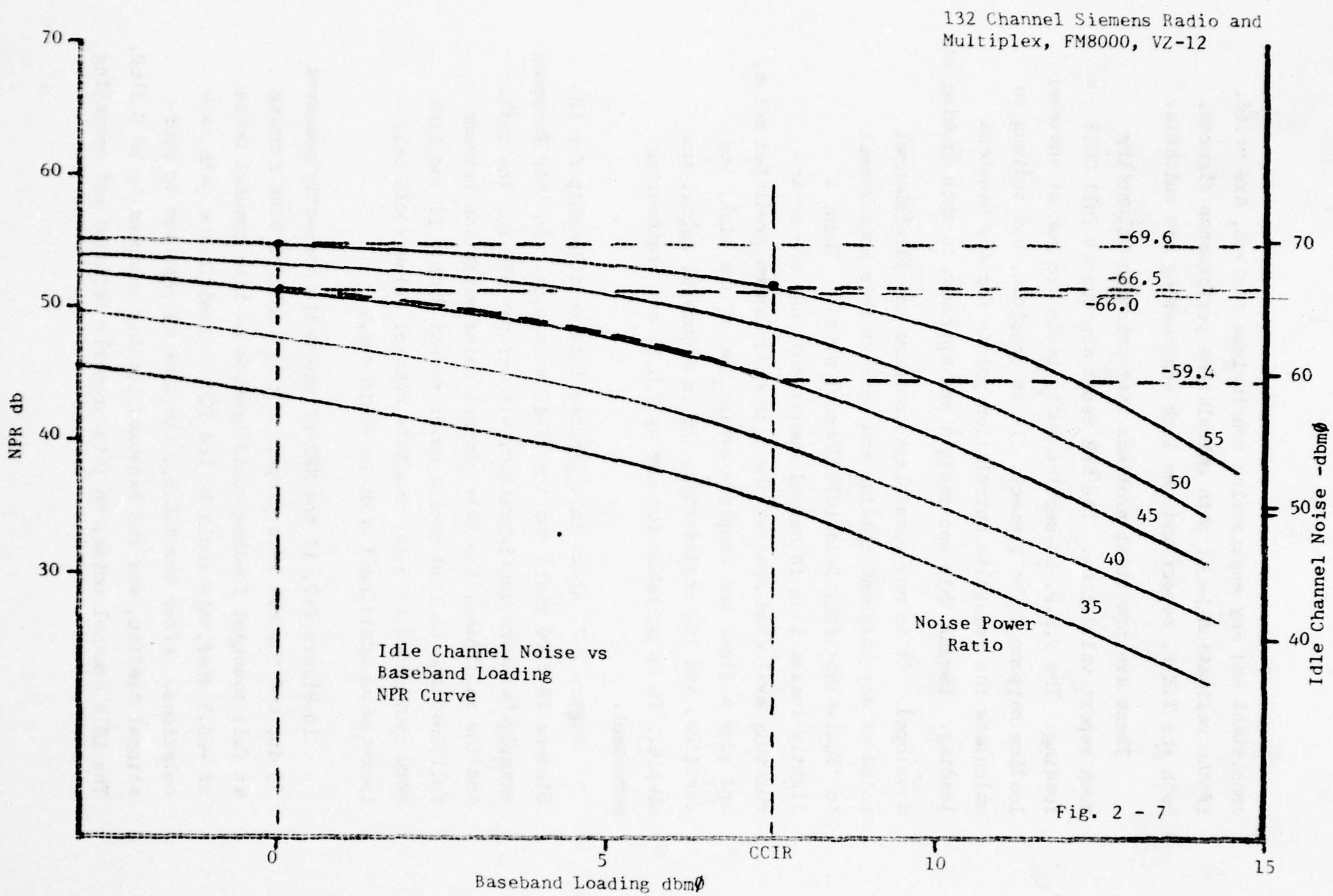
Figure 1-1, portrays the link and clearly shows that the end-to-end channel performance encompasses all of the four basic elements discussed above, including the connective cables. Clearly, if the T.E.P. characterization of these elements is accurate, the integrated performance of the four elements could be validated by assessing the actual end-to-end channel performance. Where such agreement exists, the T.E.P. report as a whole, is validated. Such agreement does not mean that the link is 'like new', but only that the T.E.P. measurements are internally

consistant and any engineering conclusions derived, are valid. If the validation is at path calculation performance figures, both the T.E.P. report and the link engineering are suitable.

There are practical problems that arise in attempting such report validation. The NPR tests are run at full CCIR loading. The T.E.P. in-service audio tests are run at whatever loading happens to be present. It is possible, but tedious to calculate the requisite correlation points for any baseband loading. During this contract, a new approach to this problem was developed. It is now possible to measure the idle channel noise at any baseband loading and convert this measurement to 'Equivalent Full Load Idle Channel Noise.' Thus, a lightly loaded link in normal operational use can be accurately evaluated against the path calculation predicted noise, and give a final and complete evaluation of the link, its conditon, and its engineering. It is accurate, quick, and simple.. It is suitable for use by T.E.P. and engineering personnel.

Figure 2-7, shows this precise interrelationship for the Siemens FM 8000 radio and the VZ-12 multiplex. In this European example hardware configuration, with proper NPR for the radio and the multiplex, the idle channel noise variation between full load and no load should never exceed 3 db. If the link were overloaded by 5 db, the idle channel noise would only increase an additional 8 db to -58.8 dbmØ.

In Figure 2-7, if the NPR of the radio correctly measured 55 db, and the mux were proper, a well designed link running at full baseband loading would produce an idle channel noise of -66.5 dbmØ,this would be the ICN derived in the path calculations. After the T.E.P., the link is returned to operational traffic, and the baseband loading observed to be Ø dbmØ. The idle channel noise, on this properly designed and operating


132 Channel Siemens Radio and
Multiplex, FM8000, VZ-12
NPR db
70
60
50
40
30
Idle Channel Noise -dbm∅
70
60
50
40
-69.6
-66.5
-66.0
-59.4
55
50
45
40
35
Noise Power
Ratio
Idle Channel Noise vs
Baseband Loading
NPR Curve
0
5
CCIR
10
15
Baseband Loading dbm∅
Fig. 2 - 7

link would be -69.6 dbmØ, extracted from Figure 2-7, at the intersection of the Ø dbmØ loading point and the 55 db NPR curve. In this event, the T.E.P. measured data and real life operation agree, and the report correlates.

Such happy agreement may not always occur. The curve and data validation may be at some unsatisfactory point; such as at an NPR of 45 - thus, some questions remain as to whether the hardware or the link engineering is defective; or the performance may be acceptable - in terms of idle channel noise in the normal lightly loaded condition - but would be quite unacceptable if an emergency were to suddenly impose full or perhaps overloaded baseband loading.

For example, suppose that the T.E.P. team 'reported' a 45 db NPR. When this link is returned to operational traffic, the idle channel noise measures -66 dbmØ. The team would report that the link meets DCS standards and was within ½ db of the calculated value. This link NPR is clearly 10 db degraded. The T.E.P. report correlates, but major alignment or repair problems still exist in the link.

In the case described above, where the NPR was 45 db, the idle channel noise appears to have degraded only 1 db. The figure clearly shows that ICN rose in reality by 4 db (-69.6 to -66 dbmØ). If this degraded link were to be fully loaded by the eruption of some hostilities or other emergency, the idle channel noise would increase along the 45 db NPR line to -59 dbmØ. Using idle channel noise as the prime parameter, the link would have deteriorated 7 db. By present standards, this would only be Amber. If this degraded hardware were overloaded by 5 db, the idle channel noise would increase an additional 10 db. The overloaded ICN would be -49 dbmØ. (10.0 db worse than a properly maintained link).

There are ways to dig deeper in the report and perhaps salvage some or all of the data. Reference to other link reports of the same type equipment can often uncover the mis-measurement, lack of correction for test level point, or other errors. In this specific example, the NPR is bad, and the wave-guide structure and path problems remain unknown.

If the idle channel noise is measured with the two receivers outputs combined, then the display chart should validate the 'combined' NPR. If but one receiver is normally on the line, then the single NPR is appropriate.

In some cases, such as VZ series multiplex, the 3KHz flat noise measurements, used for standardization throughout the T.E.P. Analysis, must be corrected. The VZ mux adds nearly 4 db more noise than the 1.5 db expected above the C msg. noise measurements. In order to retain validation capability, a 'calculated' 3KHz number is used, derived +1.5 db noisier than the C msg. measurement. This permits correlation with NPR readings that are equivalent to 3KHz flat. After the correlation, however, the real life measured noise must be used for all DCS circuit engineering over these links.

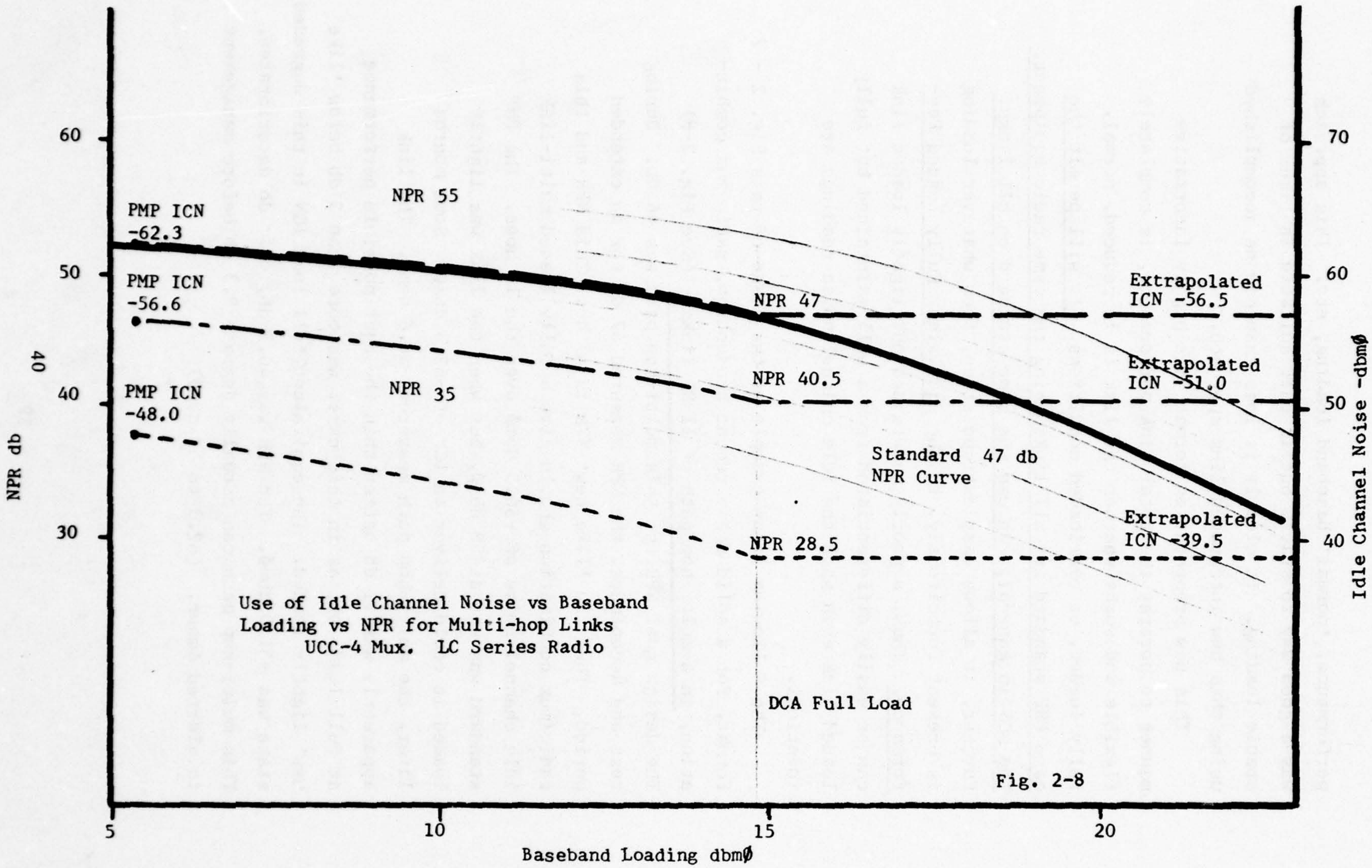
Many will recall, when the Link Assessment Program was started in the Air Force, that had appropriate standards been immediately implemented, the entire DCS would have gone 'Red.' Such an action would not have been helpful either to the field or to management, so relaxed thresholds were used. The 5 db Green, 5 db Amber, levels, however, were recognized as an inadequate but necessary first step. It is easy to see from the example just used, that the Green idle channel noise range should be about 3 db at full load, to correspond to a 5 db NPR change. Since few, if any, links operate at full baseband loading, the change in idle channel noise corresponding to 5 db NPR change is less than 3 db.

The present PMP program attempts to accomodate for the different link traffic load factors by assigning a different idle channel noise standard to each link, based upon past

performance, 'normal' baseband loading, etc. This approach was a good way to start, but is only suitable in times of stable loading. It clearly is less than can be accomplished using this new integrated link approach.

This new presentation format is a highly informative manner to portray the total link performance, is completely flexible and works whether the link is in reduced, normal, fully loaded, or overloaded conditions. It will permit the same PMP standard for all links using the same radio equipment. The DCS in general, can use the same standard on all links. Further, it allows easy extrapolation, from whatever loading is present fortuitously, to the Equivalent Fully Loaded Performance. Thus, a poorly maintained but lightly loaded link can be easily differentiated from a well maintained but fully loaded link even when the idle channel noise readings are identical.

The following is an example of the usage of this Fig. 2 - 7 format, for a solid state recent production, radio mux combination, in a multi-hop path of 11 RF links. (See Fig. 2-8) The design goal NPR for this multi-hop path was 46 db. During test and acceptance, the NPR measured 47 db for an extended period. Thus the 'like new' NPR is 47 db. This NPR and this radio/mux combination should give a fully loaded multi-link idle channel noise of -56.5 dbmØ over the 11 hops. The PMP standard was set at 58 dbmØ, but when the link was lightly loaded it could deliver an ICN of -62.3 dbmØ. Some months later, the multi-hop path measured -56.6 dbmØ. The link apparently was .1 db better than the best possible performance at full load, or, as in this case, was more than 5 db below 'like new' lightly loaded. The equivalent full load ICN in this degraded state was -51.0 dbmØ. The NPR was 40.5 db, 6.5 db deteriorated. This multi-hop path can actually degrade 9.3 db before management is alerted Amber. (62.3 to 53 dbmØ)



60
50
40
30
NPR db
40
70
60
50
40
Idle Channel Noise -dbmØ
PMP ICN -62.3
PMP ICN -56.6
PMP ICN -48.0
NPR 55
NPR 35
NPR 47
NPR 40.5
NPR 28.5
Extrapolated ICN -56.5
Extrapolated ICN -51.0
Extrapolated ICN -39.5
Standard 47 db NPR Curve
Use of Idle Channel Noise vs Baseband Loading vs NPR for Multi-hop Links UCC-4 Mux. LC Series Radio
DCA Full Load
Fig. 2-8
5
10
15
20
Baseband Loading dbmØ

If the ICN were to drop to -48 dbmØ while lightly loaded, the link would just go PMP Red, yet the ICN would degrade to -39.5 dbmØ equivalent full load ICN, and the NPR would be 28.5 db- 18.5 db degraded. Management would see just the first touch of Red, although the link should have been Deep Red-Red long before.

It seems evident that the matter of interest to the DCS is not the fortuitously loaded performance of the DCS links, rather the DCA should be interested in the "Equivalent fully loaded idle channel noise." Since the difference in performance between a lightly loaded 'like new' link and its Equivalent, fully loaded idle channel noise is only 3 to 4 db. The difference on a poorly maintained link, such as this example, is 10 db, light to full load.

This proves what is already known, a good link provides stable performance, a poor link gives highly variable results.

This author has stated many times that all electronic equipment, with no differentiation among analog, digital, tube or solid state, will degrade with time and will stabalize at a performance level about 17 db below 'like new.' This Figure 2-8, example solid state radio, clearly has validated this emperical premise.

This study is not primarily concerned with day to day matters of DCA management. This chart was developed to cross correlate T.E.P. test and in-service measurements. This chart, however, clearly has prime uses in the PMP program, in the O&M, and DCA operational evaluation programs - and in the management of the DCS.

There is one more key link parameter that must be assessed during the end-to-end link channel assessment, and that is impulse noise. This is a simple procedure requiring only a 15 minute time period. The impulse noise measuring test set is adjusted to provide three appropriate threshold levels. The test set counts penetrations of these levels. The DCA has established a nominal -18, -28, and -38 dbmØ, as the suitable threshold levels. Thus, any impulses in the high counter are within 5 db or less of the signal level normally -13 dbmØ.

These impulses disrupt any data service, and cause disturbing hits in voice connections. Impulse noise penetrating -28 dbmØ may cause data problems, and will cause teletype errors. Impulse noise above the -38 threshold can cause a variety of lesser problems. The impulse noise generated as a result of the normal - approximate gaussian noise - in channels of properly maintained links very rarely are detectable 20 db above the measured idle channel noise. On good links, this means that no impulse noise should be detected above about -44 dbmØ. Thus, any impulse noise in excess of 1 or 2 in 15 minutes is a sure alert of noise entry into the link.

Now that all the key parameters needed to describe the link are derived, there is a requirement to present the results in a suitable manner. Figure 2-9, is one format with all the relevent seven parameters plotted from Table 2-3. For someone trying to test or evaluate the link, such a presentation is very useful.

There is a summary format, Figure 2-10, that only shows the conclusions of the link performance. This will be more informative to most managers; and perhaps appropriate for engineering personnel to portray link status and to permit rapid decisions concerning where to direct further attention.

The two key elements of both management and engineering interest are:

a. loss of fade margin - so that a minor rain storm or weak temperature inversion will completely disrupt the link.

b. loss of available idle channel noise range - so that the channel is too noisy, and has less changeable range before link disruption.

The simple steps outlined in Table 2-3, cover all the calculations needed to construct such a presentation chart. The balance of the parameters are extracted directly from the T.E.P. report. The next chapter demonstrates specifically how to apply the Table 2-3, approach.

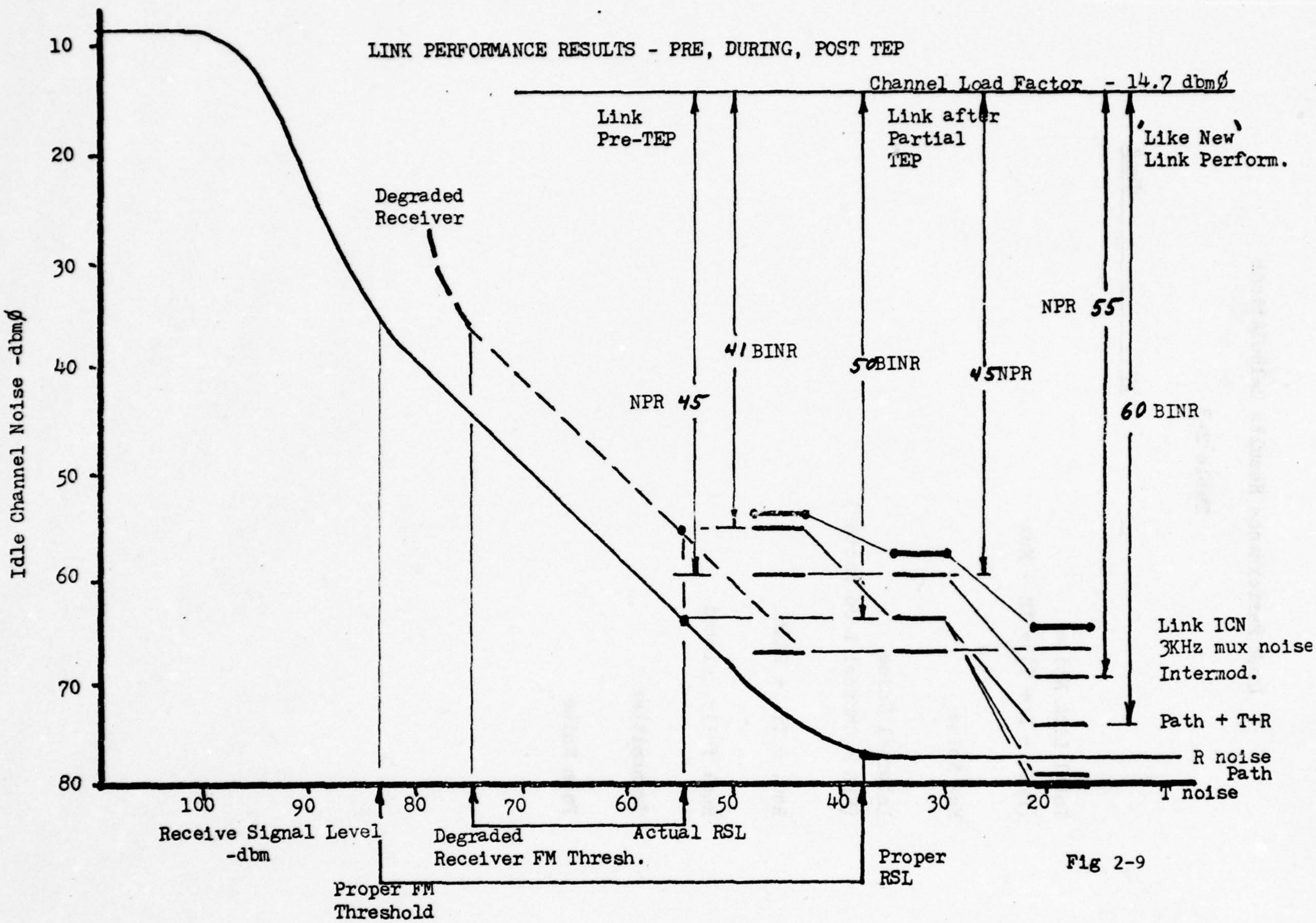
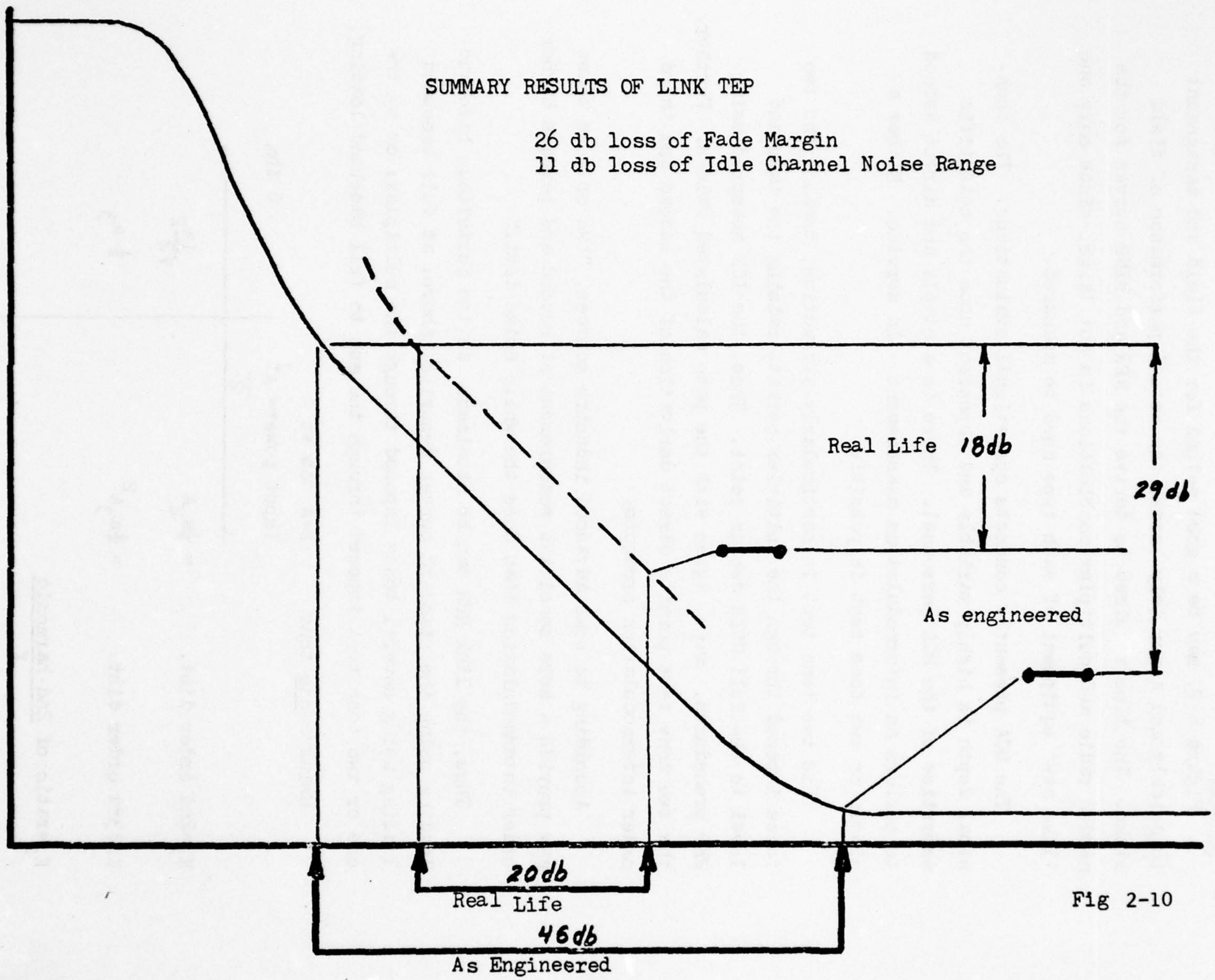

LINK PERFORMANCE RESULTS - PRE, DURING, POST TEP
Channel Load Factor - 14.7 dbmØ
Link
Pre-TEP
Link after
Partial
TEP
'Like New'
Link Perform.
Degraded
Receiver
NPR 45
41 BINR
50 BINR
45 NPR
NPR 55
60 BINR
Link ICN
3KHz mux noise
Intermod.
Path + T+R
R noise
Path
T noise
Idle Channel Noise -dbmØ
10
20
30
40
50
60
70
80
100
90
80
70
60
50
40
30
20
Receive Signal Level
-dbm
Degraded
Receiver FM Thresh.
Actual RSL
Proper
RSL
Proper FM
Threshold

Fig 2-9

Link Performance Results Calculations

Table 2-3

	pw	-dbm∅
Total Link Noise (Path + R + T) + IM + Mux		
Mux Noise		
Internal Noise (NPR + Channel Load Factor)		
Rec. + Tr. + Path		
Rec. fully quieted		
Transmitter		
Path Noise		



SUMMARY RESULTS OF LINK TEP
26 db loss of Fade Margin
11 db loss of Idle Channel Noise Range
Real Life 18db
29db
As engineered
20db
Real Life
46db
As Engineered

Fig 2-10

Figure 2-7, may be a good method for the field and management to quickly and accurately assess the actual performance of field links. The time required to derive the NPR and BINR curves for the needed radio and multiplex combinations is not large, since only one 'like new' equipment of each type need be measured.

The DCA presently conducts operational evaluations. The technical depth is highly variable and dependent upon the scientific expertise of the DCA personnel. There is a simple and direct method to perform an intermodulation measurement - in service. Either a single or two tone test is possible.

This two tone test is particularly attractive, because the two tones imposed through the multiplex permits raising the baseband level to the full CCIR design point. Thus, the ICN measured using PMP precedures, may agree with the path calculated values. Further, the two tone test permits direct derivation of the second and third order intermodulation products.

According to some advanced industry sources, "two or more tones may provide a more sensitive measurement of second and perhaps higher order intermodulation than does the white noise test."

Thus, the link NPR can be obtained: at the fortuitous baseband loading using the standard curves described above; at full baseband loading using several tones imposed through the multiplex; or by the one or two tone test imposed through the mux to full baseband loading.

Using a <u>one</u> tone	$X=A \cos wt$ Input power$= \frac{A^2}{2}$	0 dbm
K_2=2nd order dist.	$= \frac{1}{2}a_2A$	$\frac{1a_2}{\sqrt{2}\,2}$
K_3=3rd order dist.	$= \frac{1}{4}a_3A^2$	$\frac{1}{2}\, a_3$
K_2=ratio of $\frac{\text{2nd harmonic}}{X}$		
K_3=ratio of $\frac{\text{3rd harmonic}}{X}$		

Using two tones $X=A_1\cos w_1t + A_2\cos w_2t$ and $A_1=A_2=A$

	Input power$=A^2$	0 dbm
2nd order		
R_2	$= a_2 A$	a_2
3rd order		
R_3	$= \frac{3}{4} a_3 A^2$	$\frac{3}{4} a_3$
R_2=ratio of $\frac{\text{2nd order difference tone}}{A}$		
R_3=ratio of $\frac{\text{3rd order difference tone}}{A}$		

Table 2-4

Method to Fully Load a LOS Link

Page 355 Microwave Comm. NEC

STEP 11. Conclusions

There were four basic elements described early in this report plus an end-to-end link performance integrated element. This last step summarizes the results of all of the previous 10 steps. There must be a positive statement concerning each of the four basic elements, and the end-to-end link performance. There must be a statement relative to the link engineering. There may be several special conclusions concerning unusual performance characteristics of the hardware, or other features that are of interest to DCA or the O&M Agencies.

There is one very important conclusion that is needed by the engineering community; DCEC and the service development commands in particular, by the industrial production organizations in general, and also specifically by the O&M Agencies. That conclusion is how well does the assembled hardware in the field really work - for the day-to-day service in the DCS? The inverse is an appraisal of the integrated suitability of the procurement, test and acceptance, installation, training, logistic, and personnel procedures. It is also a direct measure of the effectiveness of the O&M management. <u>It is obvious that if the link is badly degraded, when initially assessed by the T.E.P. team, the integrated suitability is poor</u>. It is also evident that management should have been acting. It may not be directly evident what factor, or combination of factors is responsible, but the engineering, test and installation groups clearly must re-examine their technical contributions to assure that the degradations are not hardware or engineering based.

Step 12.

The TEP report resulting from this analysis approach is much different from that previously used. The TEP has seemingly grown to a giant pile of test measurements, with certain data extracted and tabulated. There was a reasonable RSL estimate in directly usable form. There were ICN and impulse noise readings made in-service at 'normal' operational loadings, but they bore no relationship to design performance. The bulk of the measurements were of little practical use, except to design engineers, and selected broad interest personnel. The TEP reports failed to answer specifically the engineering and operational questions needed by DCA.

The new TEP Analysis report, gives answers to specific engineering questions related to the link engineering. The 10 Steps and the associated analysis is included, along with any explanation needed to describe unusual or peculiar considerations in the measurement data or analysis. The Conclusions are, of course, one of the end desired goals. It is this 11th Step where the real outputs are converted to terms understandable by all personnel - whether technical or management. Further, 8 specific products are extracted, assembled, derived, or constructed, and made part of the TEP report.

In line with the conclusion covered in another report produced under the contract, describing a more direct and cost effective approach to TEP, only the 7 key basic TEP measurements will form a part of the TEP Report. The balance of the measurements form an Appendix.

The basic TEP report thus is composed of:

a. LOS Path Calculations

b. Tabulated Extracted Link Data

c. The 10 Steps and Requisite Analysis and Explanation (Including the 7 Basic TEP Measurements)

d. The 6 Additional Figures (Plus a & b Above) Needed to Portray the Link Information

e. The Conclusions

f. The Team Chief's Letter, as Presently Prepared is Included as Part of Conclusions.

III Application of Analysis Concept

Langerkopf

to

Bann

Introduction

This section will describe the detailed approach for the TEP analysis, and will demonstrate, by example, the simple mathematics, the approach for interpretation of the data and the presentation of the analysis results. The procedure itself is outlined step by step.

The Langerkopf-Bann link TEP report is used as the specific example.

Step 1. Reproduction

Reproduce the path calculation quieting curves, etc. sheets for use as a source of theoretical information, and hardware reference data. It also forms a part of the final TEPA.

Step 2. Extract relevant data

Extract the pertinent data from the path calculations and enter it on the data collection sheet; Table 3-1. In some cases, the data may be in dba, dbrnC,etc. Standard correction factors are used to convert all entries to - dbm or - dbmØ. Improperly derived data is corrected if the mistake is correctable. For example, the noise figure at Bann was not calculated correctly, so a -.8db correction was applied. The Langerkopf figure was correct. The path calculation NPR figure of 52.4 was corrected to 55 db as published in all other FM8000 documents.

Step 3. Perform calculations

The eight calculations tabulated in Table 3-2, are made. The equations are simple and easy to perform either manually or by use of any of the hand-held calculators having a log function. The first six calculations fully define the receiver operating parameters, and derive the intercept points described in Figure 2-1. Calculations number seven and eight are used later in the TEP analysis.

Fig 3 - 1

DATA SHEET	SITE NO. 1 (Tx)	DATE
B-2: LOS PATH CALCULATIONS	Langerkopf, Germany	30 Jan 73
	SITE NO. 2 (Rx)	LINK NO.
	Bonn, Germany	MØ331

ITEM NO.	PERFORMANCE FACTOR	VALUE	UNITS	REMARKS
1	Transmitter Power	27.0	dBm	Manufacturer's Specifications
2a	Primary Antenna Gain	75.1	dB	Manufacturer's Specifications
2b	Passive Reflector Gain	0	dB	See Attachment 2
2c	Total Antenna Gain	75.1	dB	Item 2a + Item 2b
3	Operating Frequency *(Mean)*	8.299	GHz	Link Specifications
4	Path Length	21.4	km	From Path Profile
5	Basic Transmission Loss	137.5	dB	20 log (Item 3) + 20 log (Item 4) + 92.5
6	Obstruction Loss @ K = 4/3	0	dB	See Figure 3-1
7	Obstruction Loss @ K = 2/3	0	dB	See Figure 3-1
8	Line and Miscellaneous Losses	7.3	dB	Manufacturer's Specifications
9a	Median Received Signal Level *(Single Receiver)*	-42.7	dBm	Item 1 + Item 2c − Item 5 − Item 6 − Item 8
9b	Faded Median Received Signal Level *(Single Receiver)*	-42.7	dBm	Item 1 + Item 2c − Item 5 − Item 7 − Item 8
10	Thermal Noise per Hz of Bandwidth	− 174	dBm	For T = 290 deg K
11	Receiver IF Bandwidth	6.4	MHz	Manufacturer's Specifications
12	IF Bandwidth in dB	68.1	dB	60 + 10 log (Item 11)
13	Receiver Noise Figure	12.0	dB	Manufacturer's Specifications
14	Receiver Noise Threshold	-93.9	dBm	Item 10 + Item 12 + Item 13
15	Median Carrier-to-Noise Ratio	51.2	dB	Item 9a − Item 14
16	Receiver FM Threshold	-83.9	dBm	10 + Item 14
17	Fade Margin	41.2	dB	Item 9a − Item 16 + Item 6 − Item 7
18	Climate Factor	½		Humid = 1/2 Normal = 1/4 Dry = 1/8
19	Terrain Factor	1		Smooth = 4 Normal = 1 Rough = 1/4
20	Single Receiver Outage Probability	9.255×10^{-7}		6×10^{-7} x Item 18 x Item 19 x Item 3 x (Item 4)^3 x antilog $\left[\frac{-\text{Item 17}}{10}\right]$
21a	Factor for Frequency Diversity Improvement	N/A		Freq = 4 GHz, 1/2 Freq = 8 GHz, 1/8 Freq = 12 GHz, 1/12

Fig 3 - 1

ITEM NO.	PERFORMANCE FACTOR	VALUE	UNITS	REMARKS
21b	Frequency Separation	N/A	GHz	Link Specifications
21c	Frequency Diversity Improvement	N/A		Item 21a x $\frac{(\text{Item 21b})}{(\text{Item 3})}$ x antilog $\left[\frac{\text{Item 17}}{10}\right]$
22a	Antenna Separation	5	m	Link Specifications
22b	Space Diversity Improvement	153.367		1.2×10^{-3} x Item 3 x (Item 22a)^2 x antilog $\left[\frac{\text{Item 17}}{10}\right]$/ Item 4
23	Diversity Outage Probability	6.035×10^{-9}		Item 20/Item 21c or Item 20/Item 22b
24	Radio Channel Capacity	132		Manufacturer's Specifications
25	Per Channel RMS Deviation	100	KHz	Link Specifications
26	Load Factor	7.5	dB	See text and Figure 3-2
27	Load Factor	2.37		Antilog $\left[\frac{\text{Item 26}}{20}\right]$
28	Peak Deviation	1057	KHz	Item 25 x Item 27 x 4.46
29	Highest Modulating Frequency	552	KHz	See text and Figure 3-3
30	Modulation Index	1.92		Item 28/Item 29
31	Required IF Bandwidth	4.322	MHz	10^{-3} x (2 x Item 28 + 4 x Item 29) *(NOTE: Bandwidth of Item 11 must exceed this.)*
32	Diversity Improvement Factor	3.0	dB	Figure 3-4 for type combiner used
33	FM Improvement Factor	-14.8	dB	20 log (Item 25/Item 29)
34	Correction Factor for Voice Channel Bandwidth	33.1	dB	10 log (Item 11/3.1) + 30
35	Pre-emphasis Improvement	4.0	dB	Manufacturer's Specifications
36a	Channel Signal-to-Noise Ratio, Front-End Noise Only	76.5	dB	Item 15 + Item 32 + Item 33 + Item 34 + Item 35
36b	Channel Thermal Noise, Front-End Only	12.0	dBrnCO	88.5 – Item 36a
36c	Channel Thermal Noise, Front-End Only	15.8	pWCO	Antilog $\left[\frac{\text{Item 36b}}{10}\right]$
37	Noise Power Ratio	52.4	dB	Manufacturer's Specifications
38	Baseband Width	546	KHz	Link Specifications or Figure 3-3
39a	Channel Signal-to-Noise Ratio, Idle and Intermodulation Noise Only	67.4	dB	Item 37 + 10 log (Item 38/3.1) – Item 26
39b	Channel Noise, Radio Equipment Only	21.1	dBrnCO	88.5 – Item 39a
39c	Channel Noise, Radio Equipment Only	128.8	pWCO	Antilog $\left[\frac{\text{Item 39b}}{10}\right]$
40	Fully Quieted Receiver Thermal Noise	63.0	pWCO	See Text
41a	Total Transmission Media Noise, Per Channel	144.6	pWCO	Item 36c + Item 39c

Fig 3 - 1

DATA SHEET		SITE NO. 1 (Tx)		DATE
B-2: LOS PATH CALCULATIONS *(CONTINUATION)*		Langerkopf, Germany		30 Jan 73
		SITE NO. 2 (Rx)		LINK NO.
		Bann, Germany		MØ331

ITEM NO.	PERFORMANCE FACTOR	VALUE	UNITS	REMARKS
41b	Total Transmission Media Noise, Per Channel	21.6	dBrnCO	10 log (Item 41a)
42a	Multiplex Loaded Noise	21.5	dBrnCO	Manufacturer's Specifications
42b	Multiplex Loaded Noise	141.3	pWCO	Antilog $\left[\frac{\text{Item 42a}}{10}\right]$
43a	Total Link Noise, Per Channel	285.9	pWCO	Item 41a + Item 42b
43b	Total Link Noise, Per Channel	26.1	dBrnO	10 log (Item 43a) + 1.5
43c	Total Link Noise, Per Channel	24.6	dBrnCO	Item 43b - 1.5

COMMENTS

Note #1: Transmitter power specification is measured at output of Bay. Noise figure specification includes antenna separation filter loss, therefore the 1.5 dB loss is not included in Item 8.

TABLE 3-1

TEP Report # AFCS-321 **DCA Link #** MO-331 **PMP Link #** 4014,4015 **Dated** Jan 1973

Element		Item	Link Calculated Value	Langerkopf A	Langerkopf B	Bann A	Bann B
Receiver		Noise Figure	12	11.6	10.5	11.3	11.6
		IF Bandwidth	6.4	6.3	6.4	6.6	6.3
		FM Threshold	-83.9	-81.0	-81.0	-82.0	-78.0
		Per Channel Deviation	100	✓	✓	✓	✓
		Pre-emphasis	4	4	4	4	4
		Frequency Slots	70,270,534	70,270,534	70,270,534	70,270,534	70,270,534
		Fully Quieted	—	73,75,83	74,77,84	64,73,78	66,73,79
Receiver and Transmitter		NPR (loop)	55	53,55,55	59,61,59	58,55,58	58,56,55
		BINR (loop)	60	60,63,64	61,63,64	60,62,64	60,58,59
Multiplex		NPR (loop)	-67.0	—	—	—	—
		BINR (loop)	-66.9	-69.5	-69.5	-69.5	-69.5
System		Number of Channels	132	132	132	132	132
		Receive Signal Level	-42.7	-37.5		-39.5	
		NPR (link)	55	mid 50's	mid 40's	mid 50's	mid 40's
		BINR (link)	60	60's	60's	60's	60's
		Channel Load Factor	-14.7	-14.7	-14.7	-14.7	-14.7
End to End Channel Performance		Baseband Loading	7.5	1.5	1.5	1.0	1.0
		Idle Channel Noise (3 KHz)	-63.9	-69	-69	-69.5	-69.5
		Idle Channel Noise (C mag)	-65.4	-70.5	-70.5	-71.0	-71.0

Table 2 - 1

Table 3-2

TEP Analysis Sample Calculations

Langerkopf-Bann FM 8000

I. Noise Threshold RSL = $-174 + 10 \log BW_{IF} + NF$

$$NT = -174 + 10 \log 6.4\ \text{MHz} + 12$$

$$= -174 + 68.1 + 12 = \underline{-93.9}$$

II. FMT = NT + 10 $= \underline{-83.9}$

III. FMI = $20 \log \frac{\text{per ch dev}}{f\ \text{slot}} + 10 \log \frac{BW_{IF}}{3100}$

a. $70 = 20 \log \frac{100}{70} + 10 \log \frac{6.4\ \text{MHz}}{3100} = 3.1 + 33.1 = \underline{36.2}$

b. $270 = 20 \log \frac{100}{270} + 33.1 = -8.6 + 33.1 = \underline{24.5}$

c. $534 = 20 \log \frac{100}{534} + 33.1 = -14.6 + 33.1 = \underline{18.6}$

IV. Ch Noise at FMT = $RSL_{(FMT)} - NF + 20 \log \frac{\text{per ch dev}}{f\ \text{slot}} \mp p + 139$

a. $70 = -83.9 - 12 + 3.1 - 4 + 139 = 42.2$

b. $270 = -83.9 - 12 - 8.6 - 1.5 + 139 = 33.0$

c. $534 = -83.9 - 12 - 14.6 + 4 + 139 = 32.5$

Pre-emphasis is -4 at low end, +4 at high end, and about -1.5 at the mid baseband slot by pre-emphasis curve design.

V. Channel Noise at No RF = $-N_{FMT} + FMI + 1$

a. $70 = -42.2 + 36.2 = -6$

b. $270 = -33 + 24.5 = -8.5$

c. $534 = -32.5 + 18.6 = -13.9$

VI. Receiver Fully Quieted $\geq$ No RF ch noise - 70

a. $70 = -6 - 70 = -76$

b. $270 = -8.5 - 70 = -78.5$

c. $534 = -13.9 - 70 = -83.9$

VII. Baseband loading (132 ch) $= -1 + 4 \log N$

$$= -1 + 4 \log 132 = -1 + 8.5 = \underline{7.5}$$

VIII. Channel Load Factor $= -2 - 6 \log N = -2 - 6 \log 132$

$$= -2 - 12.7 = -14.7$$

Step 4. Analyze receiver performance

The receiver intercept points just calculated are plotted on the TEP measured receiver quieting curves as indicated on Figures 3-2 and 3-3. If all of the points are within $\pm$ 1 db, the receiver is classed as 'like new'.

1. The receivers at Langerkopf are generally close to specs. The example receiver B, Figure 3-2, is degraded about 2 db at the FM Threshold. It is about 1 to 2 db de-sensitized as indicated by the less than proper noise at an RSL of -110 dbm, and the baseband noise with the receiver fully quieted is several db too noisy. A bit more O & M attention could easily fix this receiver.

The receivers at Bann, Figure 3-3, are not nearly so good. Receiver A front end is exactly as predicted as far as noise figure is concerned; but note the slight drop in noise from an RSL of -97 to -110. This indicates some interference or spurious radiation reaching the receiver. It may be unimportant operationally if the curves deteriorate no more, but that can not be assumed. There is a problem and it should be isolated and fixed. The FM threshold is still 3 db degraded even after TEP. The receiver generates considerable noise even when it is fully quieted. In this receiver A example, the 70 KHz slot is 12 db too noisy, and the mid and high slots are 6 db too noisy. If the balance of the link is 'like new,' this receiver (as well as the other one at Bann) will be the limiting noise for the lower channels.

There is one further problem indicated on the Bann receiver quieting curve. Note that the fully quieted 270 and 534 slot curves get noisier when the RSL is stronger than about -30 dbm. This is normally indicative of a defective IF and/or improper AGC action.

2. The receiver de-emphasis is proper since the 70 and 534 slot noise at no RF signal differ by 8 db ($\pm$ 4 db), for receivers at both sites.

Note: As will be noted in the Bann loop and link BINR data, the quieting curve noise performance in the low slot, and perhaps the mid slot was incorrectly measured. The instrumentation set up probably

was defective and introduced noise. This should have been caught on site as soon as the loop BINR results were obtained, and the data quite obviously did not correlate.

3. The AGC (Automatic Gain Control) curves should be approximately the same for all receivers of the class being tested - in this case FM 8000. The curves should not rise significantly at signal strength weaker than the FM threshold otherwise the signal to noise ratio degrades at low signal levels. These AGC curves are reasonable for all receivers.

4. In the earlier days of Scope Creek, the procedures called for quieting curves, as well as other relevant and highly useful preliminary measurements when first arriving at the site. It was helpful to the TEP team to quantize the size of the 'fix-it' job awaiting them. It is also helpful to all people who must understand the normal, routine, day by day status of the DCS in order to do their job effectively. This 'as found' data is useful to Management, Operations, and most importantly - to Engineers who cannot do a realistic job unless they understand the DCS. To fail to design for the real life DCS is to design for a fictitious, specious world, and that is not design at all.

The requirement for such arrival assessments has been nearly dropped, thus no documented valid pre-TEP link status can be derived.

However, analysis of previous Scope Creek reports, indicated that the average Scope Creek teams - the early Air Force TEP teams - corrected 7 to 10 db of the normally present degradations during the evaluation period. The average TEP team presently does less well. The press of arbitrary schedules, rapid personnel turnover, and failure to analyze the data on site and to correct poor or defective equipment and measurements all combine to cause poor or degraded TEP results.

DATA SHEET	FACILITY TESTED	DATE
A - 2: LINEAR GRAPH (15cm X 18cm)	Langerkopf, Germany	18 Jan 73
	DISTANT FACILITY: Bann, Germany	INITIALS: LCW/MEH
TITLE: M-5A-2: Receiver FM Quieting/AGC Curves	REFERENCE: Test M-5A (Receiver B)	

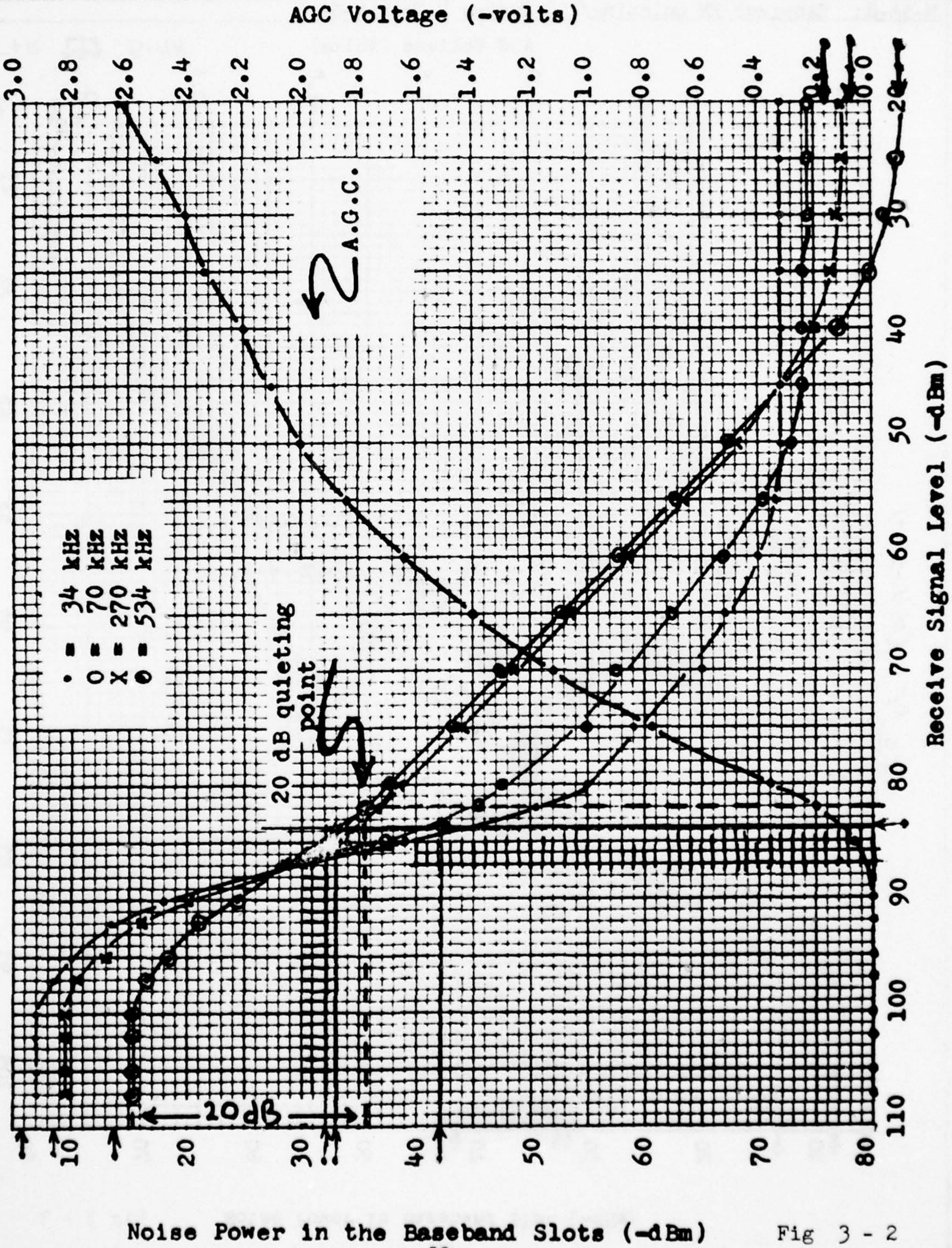


Fig 3 - 2

DATA SHEET	FACILITY TESTED	DATE
A - 2: LINEAR GRAPH (15cm X 18cm) 'A'	Bonn, Germany	26 Jan 1973
	DISTANT FACILITY	INITIALS
	Langerkopf, Germany	JM
TITLE	REFERENCE	
M-5A-2: Receiver FM Quieting/AGC Curves	Test M-5A	

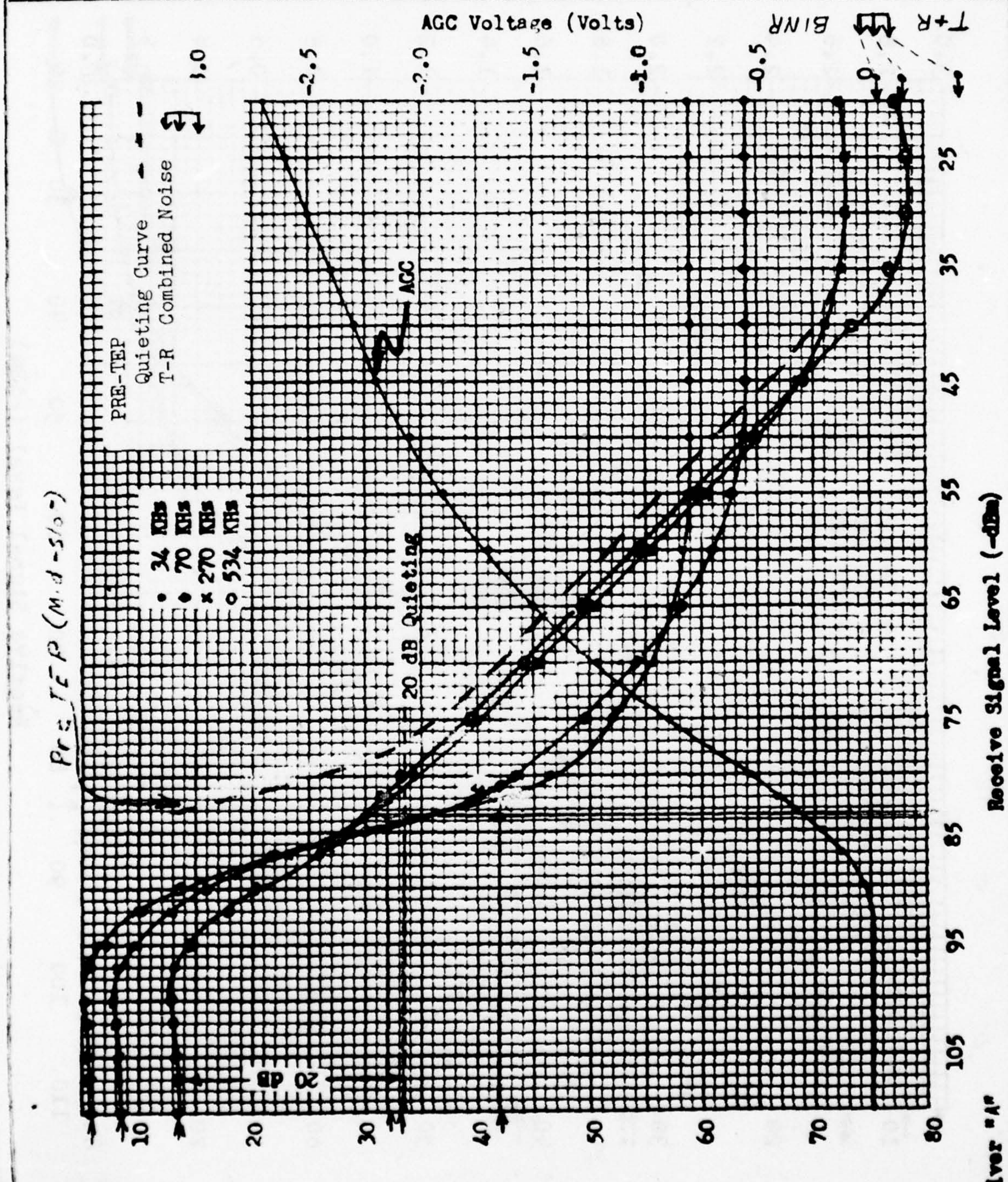


Fig 3 - 3

In the case of Bann, the dotted line on Figure 3-3, shows the first documented mid-slot quieting, and clearly portrays the improvement achieved on receiver A by the TEP team. The FM threshold was improved 6 db although the other defects were left uncorrected. Thus, the expected degradation is about what it always has been - approximately 14-18 db down from 'like new' for the link.

Step 5. Analyze the field data to validate the RF Carrier Determining Elements (Major Question I)

After the receivers have been measured and the quieting and AGC curves plotted, the received signal level (RSL) can be extracted by observing the AGC voltage as the receiver is in normal use and converting the AGC voltage to RSL. The fact that the receiver may degrade does not invalidate the results. It is only required that the RF signal input vs. AGC curve be accurate.

Clearly there were problems upon arrival at both Bann and Langerkopf sites. Bann observed 10 db difference in RSL between the two receivers. Langerkopf had agreement between receivers, but not with Bann. After a complete antenna alignment, the most degraded path to Bann picked up 19 db and the best gained 10 db RSL. Langerkopf gained 20 db, 100 times more signal, on both receivers. There was still about a 2 db disparity between the reciprocal paths at the termination of the TEP testing.

The resultant RSL, however, is 2 to 4 db stronger than predicted. Normally this is a pleasant surprise, but these sorts of disparities are indicative of substantial errors in engineering loss estimates, significant changes during installation that change the design, or poor path criteria.

The team chief letter stated, that previous Scope Creek data had validated an RSL of -39 dbm. Thus, the correct value would seem to be nearly 4 db stronger than calculated. These discrepancies are too large to ignore and should be examined and explained.

In spite of the previous TEP proved RSL of -39 dbm, the two sites had allowed the signals to drop 10 and 20 db. This magnitude degradation should have had attention of all mangers all the way through DCA HQ.

Step 6. Analyze the field data to validate the performance of the transmitter-receiver elements and the path for noise.

a. Loop BINR

1. The loop BINR data is examined first to determine whether any transmitter-receiver pair is noisy. Transmitters are supposed to be 3 to 5 db quieter than the receivers.

(a). Bann Transmitter A to Receiver A

		BINR		ICN
BINR measured	70 slot	60 db	=	-74.7 dbmØ
	270 slot	62 db	=	-76.7 dbmØ
	534 slot	63 db	=	-77.7 dbmØ

The BINR is converted to ICN by the addition of the channel load factor of 14.7 db. The noise directly extracted from receiver A quieting curve:

70	64 dbmØ
270	73 dbmØ
534	78 dbmØ

There is agreement generally in the 534 and 270 slot, but the 70 KHz slot does not agree by 10 db. This disparity should have been checked by the teams. However, loop and link BINR tests will resolve the question as to which data is correct.

Since the loop BINR (combined T + R) noise is not significantly noisier than the receiver calculated values, the receiver is presumed to be acceptable. It appears that the transmitter met normal design criteria and was 5 db or more quieter than the receiver. Thus, in later tests T_A may be rated at:

		BINR	ICN
70	=	65	-79.5 dbmØ
270	=	67	-81.5 dbmØ
534	=	68	-82.5 dbmØ

A similar analysis indicates that receiver B is slightly noisy.

(b). Langerkopf T_B - R_B

	slot	BINR	ICN (converted)
BINR measured	70	60	-74.5 dbmØ
	270	63	-77.5
	534	64	-78.5

The noise extracted from the receiver$_B$ curves directly is:

70	-74.5 dbmØ
270	-77.5
534	-83.0

The agreement is excellent. Thus, simple math shows that T_B performance is:

slot	BINR	ICN
70	64	-79 dbmØ
270	67	-82
534	64	-78.5

Transmitter 'B' appears to be a bit noisy in the high slot and limits the joint T-R performance, but still meets design noise specs.

b. Link BINR

2. Now that the transmitters and receivers (in practice more permutations would be examined to be sure all were acceptable) are assessed, the link BINR is analyzed. It is obvious from examination of Figure 2-5, that the noise of the link is the noise of the transmitter + receiver, noise of the wave guide structure and path. Thus, the path noise can be directly calculated using loop BINR, or the individual performance figures derived.

BINR (link) = (BINR (Rec) + BINR (Tr) + Path Noise (Wave guide + path)

There are two possible methods to actually solve the link BINR question. The loop measured BINR is presently determined with the receiver fully quieted in all baseband slots. The link BINR is measured at the operational RSL and often one or more slots are not fully quieted. Thus a direct numerical comparison is not proper.

It is possible, and in some cases an additional loop BINR is conducted at the measured link RSL. This provides a BINR plus receiver noise at less than full quieting. The above equation can then be solved directly using the BINR (at operational RSL) figure. This BINR should be added as an additional step to the TEP--the time required would be

only a minute or two, and the measurement provided would ease data reduction.

There is another approach that is acceptable. Since in a properly operating link, the transmitter noise is 5 db or more less than the receiver, and is independent of the link RSL, it can normally be ignored. The receiver operationally quieted noise is the determining figure. The receiver quieting curve permits direct extraction of the noise for each slot at the operational RSL. In the case of Bann the receiver slot noise at -39 dbm RSL is 59, 60, 63 dbmØ in the three slots. These figures are used directly as indicated below to validate the path noise. Note: the actual noise readings were taken from the quieting curves conducted at Langerkopf since the Bann curve is suspect. In a properly checked TEP the Bann curves would have been redone correctly.

(a) Bann link BINR = 60 db in all slots for the R_A at Bann from T_B at Langerkopf.

slot	BINR (link)	BINR (T+R @ -39		calculate path noise)
70	60	59	=	65+
270	60	60	=	64
534	60	63	=	63

There appears to be some slight noise in the high slot, but since the composite is still 60 db, design specs are met.

The BINR is the high slot for the path and waveguide is 63 db. That converts to a high channel ICN of 63 + 14.7 = 77.7 dbmØ = 16.9 pw.

The path calculations predicted (item 36b) 15.8 pwc = 22 pw in the high channel. This is close agreement and proves that the waveguide structure does not introduce any significant or measurable noise.

This measurement further proves that the R_A at Bann had noise introduced into the quieting curve by poor instrumentation cabling, since both the loop and link BINRs were quieter than the receiver curve measured directly.

(b). Langerkopf link BINR, Langerkopf R_B from T_A at Bann

The logic of extracting the receiver noise from the quieting curve at the operational RSL of -39 dbm is used here also. The BINR (RSL = -39) figures are 59, 60, 63. As indicated in the tabulated solution below,

the link BINR is quieter than the loop measurement, although still passing design specs. This again emphasizes the importance of good cabling practice, proper grounding of instrumentation, and careful measurements.

slot	BINR (link)	BINR (T+R @ -39)		path noise
70	62	59	=	65+
270	62	60	=	68
534	63	63	=	69

There is no waveguide or path problem evident here. All Design specs are met. The link BINR for the high slot is 63 db, and again validated the engineering predictions of path noise and shows that waveguide noise is not measurable.

Similar analysis can be made for other combinations if problems seem to warrant such examinations. There is no such demonstrable need in this link, from a path and waveguide standpoint.

c. All T-R combinations in the Bann to Langerkopf direction are acceptable with one exception. Bann T_A was acceptable to Langerkopf R_B, but slightly noisy to R_A. R_A itself is quiet, so a question is raised whether some waveguide structure unique to R_A may be responsible. That, however, is not the cause, since Bann T_B to R_A was acceptable. The question then is addressed to T_A, but it was proved acceptable to R_B. Thus a slightly questionable measurement is likely.

In the Langerkopf to Bann direction again the several combinations are a bit noisy, although marginally meeting design specs. The slightly noisy Bann T_B to R_B loop BINR is substantiated by a slightly noisy link measurement Langerkopf to Bann R_B. T_B at Bann is acceptable.

This last analysis is for O & M use, since the path and basic waveguide structure have proved acceptable.

Step 7. Analyze the TEP NPR data to examine the link baseband to baseband for equipment, RF related structure and path intermodulation distortions.

a. Loop NPR

Question 6a, posed at the beginning of Step 6, is partially answered - the noise is acceptable. Question 6b, is also partially answered - the path noise and waveguide noise is acceptable. The remaining issues relate to radio, transmitter and waveguide/path intermodulation and distortion questions. There questions are addressed by examining the NPR - noise power ratio-first in loop, then in link. Unfortunately, there is no simple way to analyze the individual NPR numbers - as there was with BINR (noise), unless the transmitters and receivers are aligned using a link analyzer to absolute linearity. So far, few if any receivers are ever really linear and the composite Transmitter/Receiver pair can be better, worse, or the same as the receiver alone. Seemingly better operation is possible - and often is in TEP - since the transmitter can be adjusted to equal but reverse distortion of the receiver. The pair appears linear, and in fact that pair will be. However, when either the transmitter or receiver is employed with any other unit, the results will be even more distorted. The Bann-Langerkopf link is a good example of compensated distortion adjustment.

1. Bann loop NPR's were:

slot	T_A-R_A	NPR	T_B-R_B	NPR
70		59		60
270		60		58
534		62		59

These numbers are very good - in fact they are so good that they clearly alert that the hardware was compensated, rather than linearized. The degree of compensation and the amount of linearization can be ascertained during the link tests.

2. Langerkopf loop NPR

slot	T_A-R_A NPR	T_B-R_B NPR
70	55	59
270	55	59
534	55	59

T_A-R_A appears both good and reasonable. The T_B-R_B is clearly compensated. Unfortunately, in both cases, the compensation is for non-operationally interesting in-station T-R pairs. The useful alignment linearity will be ascertained during the link tests.

b. Link NPR

1. The link NPR data from Langerkopf to Bann is as stated:

Langerkopf	to	Bann
T_A	mid 40's	R_A and R_B
T_B	mid 50's	R_A and R_B

This would clearly indicate that R_A and R_B at Bann were both reasonably linear and that T_B at Langerkopf was also linear since it matched two receivers. Clearly T_A at Langerkopf is suspect since it fails to achieve results with either of two good receivers. Thus, a performance matrix looks as follows:

Langerkopf	Bann
T_A (mid 40's)	R_A and R_B (high 50's)
T_A (high 50's)	

The transmitter high 50's plus receiver high 50's produces mid 50's total NPR when equipment is nearly linear.

2. The link NPR data from Bann to Langerkopf is:

Bann	Langerkopf
T_A	R_A mid 40's R_B mid 50's
T_B	R_A and R_B mid to high 40's

Clearly T_A at Bann and R_B at Langerkopf give the only good results and these two elements may be linear. Since no other pair is good, this linearity must be questioned. T_B at Bann is not up to specs with either receiver at Langerkopf and is degraded. R_B is again better than R_A. A performance matrix is:

T_A high 50's (?)	R_A mid 40's
T_B high 40's	R_B high 50's (?)

These individual matrix ratings work very well when equipment is at or near specs - above NPR's of 50, but become increasingly unreliable in the 40's or below.

The output desired, however, is the resolution of the remainder of the questions at the start of the section. Clearly some of the transmitters and receivers are non-linear and introduce significant distortion. That is a matter for O & M attention. The presence of one good link measurement in both directions normally permits the determination that the major portion of the waveguide structure is acceptable, and that the path introduces no distortion. One good link is two transmitters at one end and one good receiver at the other, or one transmitter and two good receivers. In either case, the NPR should be approximately 55 with both equipment pairs used - this proves linearity. The possibility of problems in the waveguide structure uniquely associated with a transmitter or receiver still remains. Certainly all transmitter and receiver distortions should be corrected first, before waveguide or path problems are pursued, since we know for sure that compensating non-linearities exist at both Bann and Langerkopf.

c. NPR vs baseband loading

The NPR vs baseband loading curves for both sites were generally of the correct shape. They were, however, peaked well above 55 db - a symptom of compensated non-linearities. These compensations were ideally demonstrated by the less than acceptable link NPR's by many transmitter and receiver combinations.

The curves, however, show generally the proper shape, they peak at the correct loading, etc. These curves were <u>not</u> used to derive the composite NPR vs idle channel noise vs baseband loading used later in this report in the audio to audio data/link validation. Reference Figures 2-7, and 3-4. Rather a curve was employed from another TEP report of the same class of equipment, that was proper in all aspects. Only one such curve per class of equipment need be measured.

Step 8. The Multiplex Equipment

The test teams performed most of the routine tests and the two sites produced data much the same.

a. Phase jitter about 1^{o}

b. Distortion -37 db

c. Frequency offset $\leq$.1 Hz (except group 6 that is translated with a separate un-synchronized oscillator = 1.7 Hz.

d. Level control through the mux was fair with about 40% of the levels with more than 1 db variations through the stages. The levels going in and emerging at the audio jacks had level excursions of 4.3 db at Bann and 6.7 db at Langerkopf. This sort of variation introduces considerable unnecessary noise, and demonstrates poor operational management.

e. The idle channel noise in the baseband looped unloaded mux is -71.3 dbmØ. This is good. There is another feature that is common to this Siemens multiplex. There is more than 1.5 db difference between the C msg. and 3 KHz measurements. -71.3 dbmCØ calculates to be about -69.8 dbmØ. It actually measures -65 dbmØ. There is a difference of nearly 5 db. One of the team chiefs complied with the procedure to examine the channels to determine the cause of the disparity. In the 8 channels he checked, the 3 KHz noise was completely determined by tones on 5, mostly determined by tones on 1, and part of the disparity created by tones on 2. The tones were 50, 100, 150, and 400 Hz, clearly prime power related. The entry point was not addressed. However, only the 400 could possibly have traversed the voice channel. The same 3 KHz and C msg disparity exists at Bann and in other VZ-12 sites so that the problem is multiplex or mux installation related. This matter is important since 5 db of reduced noise is achievable if this common problem were resolved.

In similar cases on at least 4 other multiplexs, this class problem was easily solved. All that was required was to separate the multiplex power supply a few feet from the channel entry hardware and both tones and noise were reduced to proper levels - below multiplex basic noise.

In general, the Bann and Langerkopf multiplex are standard, and behave like all other Siemens mux.

The measurement of idle channel noise while the mux is looped at baseband, and while the mux is unloaded was discussed above. This idle noise reading is identical in principle to BINR as measured on the radio.

There is a standard test to measure the mux NPR although neither team chief tried,'because of lack of test equipment.' Most teams also fail to do this test. However, the test was done on this type multiplex on another link and the resultant NPR curve was used, in conjunction with the BINR data above to create the composite curve for a following Step. Figures 2-7 and 3-4.

Step 9.

There are no test procedures to test the various cables at either end of the link. In this link characterization there were two problems identified that resulted from poor cables. Bann found high impulse noise across the whole baseband that was identified to a bad baseband cable at Langerkopf. Bann also found some cross-talk at a -55 dbmØ level from one Bann transmit baseband cable to another transmit baseband cable. These would have been found early had cables been directly assessed.

Step 10. End to end link performance.

The last remaining step is to check the total end to end link performance. This step is the only sure way to prove the TEP report data correlation. The data as plotted on Figure 3-4, is also a valuable way to portray true operational link status. ICN vs baseband loading vs

NPR curve as shown in Figures 2-7, and 2-8, is for the FM 8000 radio and VZ series mux. Thus, this figure is the appropriate one to use for this Bann to Langerkopf link.

The idle channel noise measured at Bann and Langerkopf is plotted at the average baseband loading. See Figure 3-4. Both Bann and Langerkopf plot about 1 db above the 55 db NPR curve. This approximately 56 db curve is extended to the fully loaded - CCIR - line. This intersection of the NPR and the CCIR baseband loading line equates to an equivalent fully loaded idle channel noise of -66.8 dbmØ.

The path calculations predict a fully loaded link idle channel noise of -63.9 dbmØ. This difference of 2.9 db is too much. Already noted previously is the incorrect NPR used - 52.4 db vs a proper 55 db. This 2.9 db error appears to nearly correct the disparity. Actually, the idle channel noise plots at an NPR of 56 db.

The other validation question is to check and see whether the idle channel noise vs baseband loading indicated NPR of 56 db is proper.

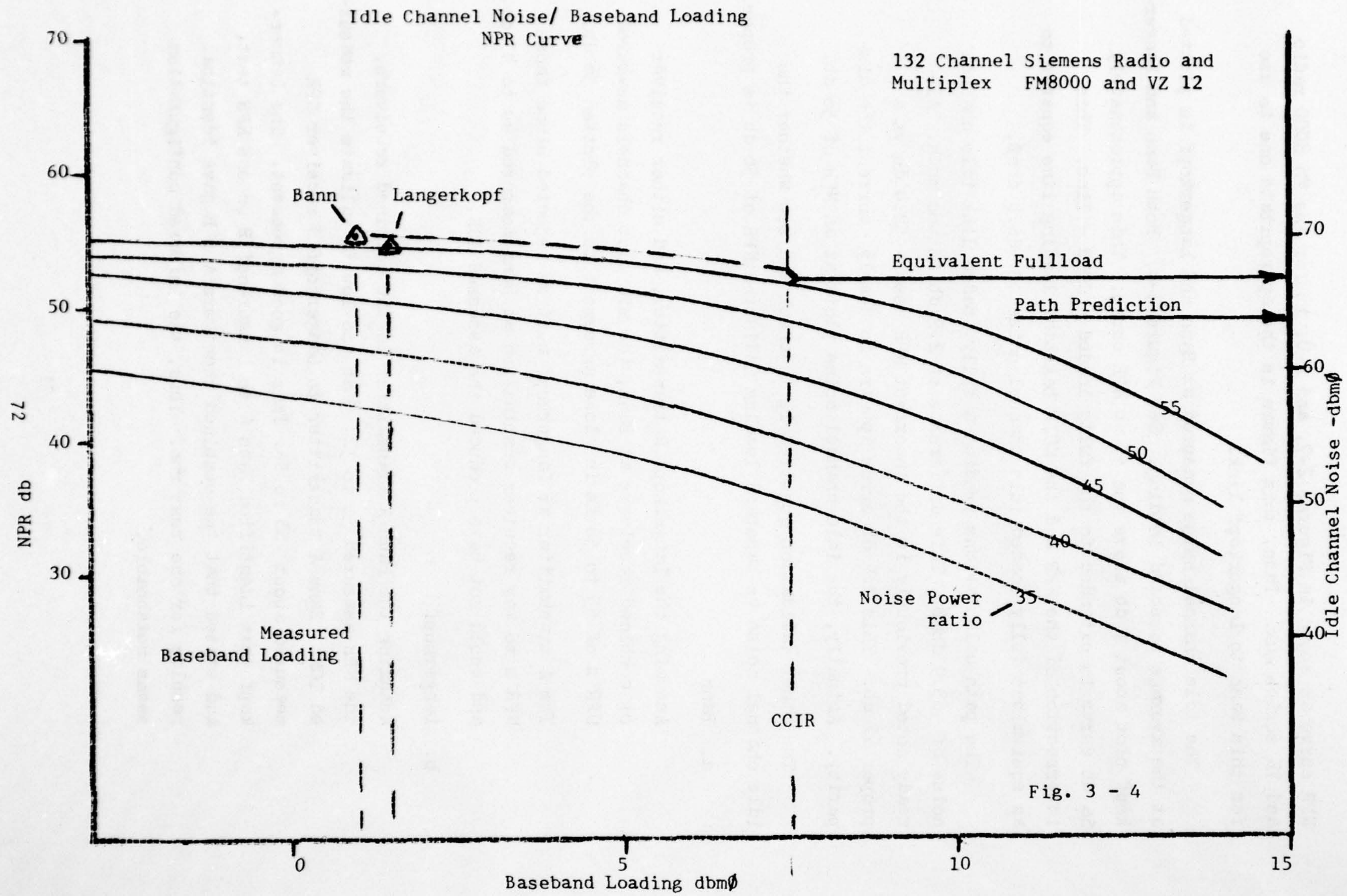
a. Bann

Assuming the Langerkopf B transmitter, and either receiver or combined receivers at Bann, the mid slot channels measured NPR's of 55 to 58 is in close agreement to the plotted 56 db.

The A transmitter at Langerkopf must be rejected since those NPR's to any receiver combination at Bann measured 44 to 47 db, and could not have produced the assessed ICN.

b. Langerkopf

Assuming the Bann A transmitter to the combined receivers, the NPR measured 51 to 52, 5 db too low to validate the measured ICN. Bann A transmitter to Langerkopf B receiver NPR measured about 55 to 56. This is good agreement. The Langerkopf team identified Bann A to Langerkopf B on one NPR test, and stated that the combined receivers A & B gave identical results for one test run. Thus, the inferred configuration seems reasonable.



Idle Channel Noise/ Baseband Loading
NPR Curve
132 Channel Siemens Radio and
Multiplex FM8000 and VZ 12
Bann
Langerkopf
Equivalent Fullload
Path Prediction
Measured
Baseband Loading
CCIR
Noise Power
ratio
55
50
45
40
35
NPR db
70
60
50
40
30
Idle Channel Noise -dbmØ
70
60
50
40
0
5
10
15
Baseband Loading dbmØ

Fig. 3 - 4

It should be remembered that the NPR curves, and the ICN for a link using a combiner, should be 2 to 3 db better than one receiver alone. Thus, the Figure 3-4 curve must match the operation of the hardware. In this Bann-Langerkopf link, the combiners were not operating correctly and no such gain occurred - if receiver A and receivers A and B gave identical results.

c. The impulse noise over this example link is indicative of hardware problems. Bann received less than 1 hit above -19 dbmØ, one hit above -29 dbmØ and 3 above -39 dbmØ, all for a 15 minute period. This is good performance.

Langerkopf is quite a different story. There are two hits above -17 dbmØ, approximately the signal level. 22 hits above -27 dbmØ, and 44 above -37 dbmØ, again for a 15 minute period. These are average figures over a 6 hour period. However, the noise is not equally disposed around the clock. The impulse noise is 6 to 8 times as heavy in the afternoon as it is in early morning. The noise is not related to idle channel noise, since ICN does not show this degraded performance in the afternoon.

The source of the high impulse noise at Langerkopf was not isolated by the TEP team specifically, however, the team at Langerkopf noted in the team chief letter that signalling, from Ramstein AFB on the two PBX access Autovon lines, was at +10 dbmØ. The team noted that these "dial tones caused noise and intermodulation every time." This is not surprising. One dial tone is more loading than the radio was designed to handle. Two tones provide nearly 4 times the design baseband loading of +7.5 dbmØ.

Refering to Figure 3-4, the imposition of one dial tone would move the baseband loading from the 'normal' +1.3 db to over +10 dbmØ and the idle channel noise would increase abruptly from -70 to -64 dbmØ. When two tones are present, the ICN would drop to -58 dbmØ on all channels. This is a 6 db additional increase. As can be seen in the TEP report, the impulse noise also goes very high. This is what always happens when the baseband is heavily overloaded.

Reference Figure 3-4. The link NPR upon arrival of the TEP team was in the low to mid 40's and possibly worse. The poorer NPR configurations may have been in service. The impulse noise tests were certainly conducted prior to any significant repair on the hardware, consequently, a full analysis as to the source of the impulse noise is not possible. These tests were not conducted again after the antenna realignment, equipment repair, and hardware adjustment. The key point remains, however, Langerkopf will always generate considerable impulse noise until the poorly engineered Ramstein access lines are corrected. There may also be other problems, such as the later discovered defective baseband cable noise, but these are difficult to isolate while swamped by an obvious and known signalling problem.

The TEP team also had difficulty at Langerkopf with direct impulse noise pickup in instrumentation and inter-test set cabling. The 'usual' observation was made that the grounding was bad. The fact that it was 'usual,' neither invalidates, nor verifies the truth of the observation.

However, clearly a problem exists, at Langerkopf, and it does not at the Bann end of the link. The identical instruments and at least presumably the same test procedures failed to sense this high impulse noise at Bann. Although the receiver quieting curves did demonstrate some noise pickup, neither the NPR nor BINR tests showed such problem. It is easy to

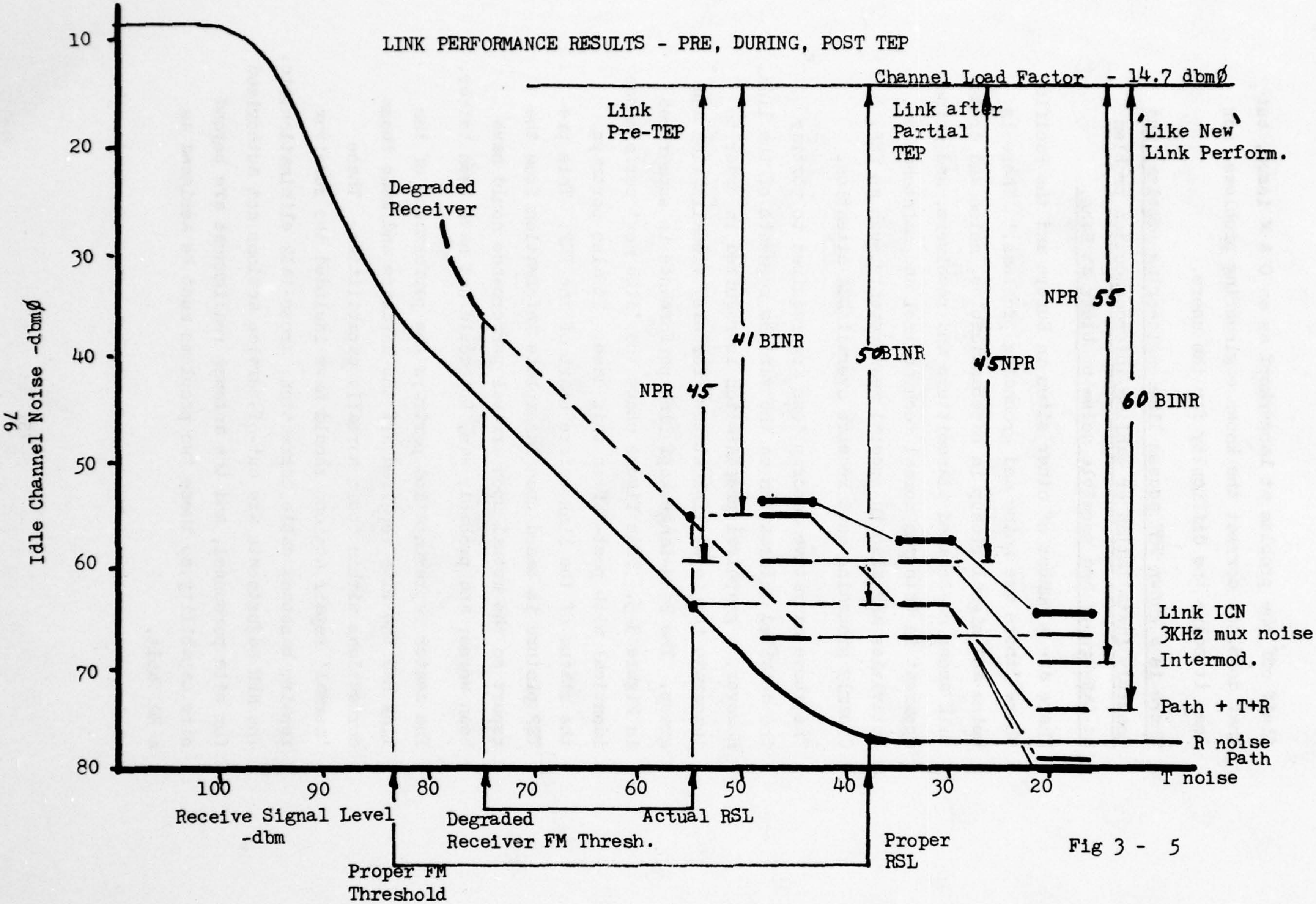
fluff off the problem at Langerkopf as an O & M issue, but that does not correct the known engineering problems, nor does it solve the difficulty for the users.

There is a known VON access line engineering problem, and possibly installation or cabling/interconnection problem at Langerkopf and possible noise problems at Bann.

There are a number of other sites in Europe and the Pacific where 'there are noise and grounding problems.' There is noise and signal pickup in baseband cables, noise and cross-talk among co-located transmitters and receivers, and noise apparent in both the normal tech control and maintenance activities and also in special measurements such as TEP. Clearly grounding must receive overall DCA attention.

The above narrative descriptions are required to portray the detailed information on the various segments of the link. However, a graphical presentation is required in order to integrate the total link status, for easy visualization and grasp. The Bann-Langerkopf link performance is summarized in Figure 3-5. This figure shows the 'like new' performance identical with post-TEP in this case. It also portrays the status of the link before start of the TEP. This pre-TEP picture is based upon incomplete information from the report so the actual upon arrival performance could have been worse, and probably was, but could not have been better.

The center representation portrays the performance of the link had the site repaired all the hardware and made those corrections within their normally capabilities. These 'normal' repair actions should have included the receiver repair, baseband cable correction, cross-talk elimination,etc. The NPR adjustments are out-of-service actions not authorized for site personnel, and the antenna realignment are beyond site capability,so these two problems must be assigned as a HQ fault.



LINK PERFORMANCE RESULTS - PRE, DURING, POST TEP
Channel Load Factor - 14.7 dbm∅
Link Pre-TEP
Link after Partial TEP
'Like New' Link Perform.
Degraded Receiver
NPR 45
41 BINR
50 BINR
45 NPR
NPR 55
60 BINR
Link ICN
3KHz mux noise
Intermod.
Path + T+R
R noise
Path
T noise
Idle Channel Noise -dbm∅
10
20
30
40
50
60
70
80
100
90
80
70
60
50
40
30
20
Receive Signal Level -dbm
Proper FM Threshold
Degraded Receiver FM Thresh.
Actual RSL
Proper RSL

Fig 3 - 5

The pre-TEP performance of the link was very poor, with a fully loaded equivalent ICN of -56 dbmØ. The receivers are operating far from the fully quieted portion and were for all practical purposes in a tropo mode. It is obvious that the link was path and hardware noise limited with a BINR of near 41 db and poor RSL. This means that even with the degraded NPR of 45, the ICN is nearly oblivious to the intermodulation noise. It is evident that the link NPR of 45, later verified when the receiver was repaired, and the RSL corrected, could not have been accurately measured. The BINR would have nearly swamped the NPR figure. The mid-slot for example would have measured NPR 39.5/BINR 41, giving a true NPR of 45 db. The team chief letters state that the following maintenance was performed that relates to NPR, including;

a. Modulater tube replaced
b. Mixer retuned
c. Antenna separation filter retuned
d. IF retuned for proper bandwidth
e. Transmit klystron replaced
f. Demodulater retuned
g. AFC realigned

Lack of full documentation precluded full dissection, but test data taken during the TEP suggests that the pre-TEP link performance could have been considerably worse than the 45 db first measured.

The 'during-TEP' performance, after the hardware items were repaired, but before the NPR and antennae realignments, was still not acceptable. The hardware BINR is greatly reduced, and the NPR is now the limiting performance parameter, as it should be, however, the actual measured ICN at the +1.3 dbmØ average light loading converted using the new technique developed under this contract, to an 'equivalent fully loaded ICN of -59.5 dbmØ.

Table 3-3

Link Performance Results Calculations

	Like New		Link with Partial TEP (Hardware Repaired)		Pre-TEP	
	PW	-dbmØ	PW	-dbmØ	PW	-dbmØ
1. Total Link Noise (Path + R + T) + IM + Mux	347	-64.6	1680	-57.7	3952	-54.0
2. Mux Noise	200	-67	200	-67	200	-67
3. Intermod Noise (55+14.7)=69.7	107	69.7				
(45+14.7)=59.7			1072	59.7	1072	-59.7
4. R + T + Path	40	-74	408	-63.9	2680	-55.7
5. Receiver Noise	18	-77.5	18	-77.5	2290	-56.4
6. Trans. Noise	10	-80	10	-80	10	-80
7. Path Noise (C/N Related)	12	-79.5				
With -55 RSL			380	-64.2	380	-64.2

Table 3-4

Link Performance Computation Guide

Calculation #

7. Path noise = Carrier to Noise Ratio + Diversity Improvement + FM Improvement + $10 \log \frac{IF_{BW}}{3100}$ + Pre-emphasis

   This value can be extracted from the quieting curve also.

6. Transmitter performance = from loop/link analysis

5. Receiver performance = from loop/link analysis

   This value can be extracted from the quieting curve also.

4. Transmitter + receiver noise = addition of #6 and #5 above

3. Intermodulation noise = NPR + Channel Load Factor

2. Multiplex noise = 3 KHz noise from mux analysis

1. Total link performance = Path noise + (T_x + R_x) noise + Intermodulation + Mux noise = #7 + #4 + #3 + #2

The final post-TEP link performance on one good combination in each direction, fully validates the link engineering and agrees with the corrected path calculation, (55 db NPR and -39 dbmØ RSL). The link engineering apparently mis-assigned some waveguide loss figures, or assumed an incorrect antenna gain, and an error of 4 db is too large to ignore. This issue should be resolved.

Figure 3-6, is the summarized TEP results.

	Design	Operational Real Life
Fade Margin	46 db	20 db
Fully loaded ICN performance	-64.6	-54.0
Possible ICN dynamic Range	29 db	18 db

The fade margin degradation shows that even relatively common rain storms, and other weather effects such as inversions, would cause severe link problems, and would often disable the path. The RFO's for such outages,(when none should actually occur), is normally atributed to 'weather,' but clearly the proper RFO very poor maintenance - high BINR; poor maintenance - degraded NPR; poor maintenance and poor management - very severe RSL deterioration; poor HQ supervision - severe RSL decay.

Table 3-3, and the associated calculation outline shows the method of computing the specific values for plotting Figure 3-5.

<u>Step 11.</u> Conclusion

The conclusions at the termination of this TEPA can be stated:

a. The RF carrier determining elements are acceptable. The path calculations, however, understate the RSL by more than 3 db, and this should be examined and resolved.

b. The transmitters and receivers are generally not in 'like new' condition, but can be brought to acceptable status by proper maintenance, since at least one transmitter and one receiver at each site was so repaired.

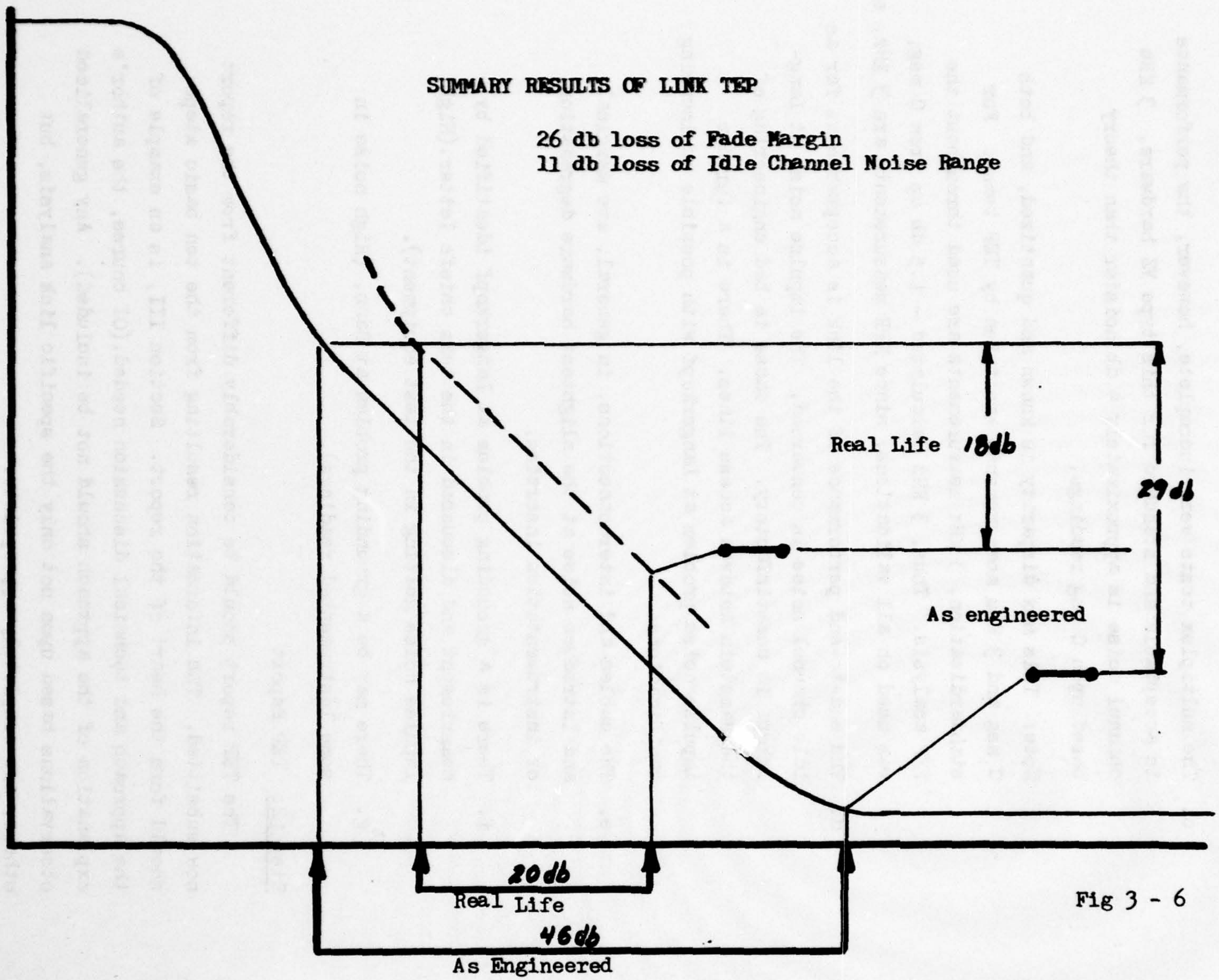

SUMMARY RESULTS OF LINK TEP
26 db loss of Fade Margin
11 db loss of Idle Channel Noise Range
Real Life 18db
29db
As engineered
20db
Real Life
46db
As Engineered

Fig 3 - 6

c. The multiplex tests were incomplete, however, the performance is acceptable and standard for this type VZ hardware. 3 KHz channel noise is approximately 4 db noisier than theory based upon C msg readings.

Note: This mux disparity is known and quantized, and both C msg and 3 KHz measurements are taken by TEP teams. For standardization, 3 KHz measurements are used throughout the TEP analysis. Thus, 3 KHz calculated - 1.5 db up from C msg, was used on all validations, since NPR measurements are 3 KHz, etc.

d. The end-to-end performance of the link is acceptable as far as idle channel noise is concerned. The impulse noise at Langerkopf is unsatisfactory. The cause is bad engineering of the Ramstein Autovon access lines. There is a further impulse noise problem at Langerkopf with possible engineering ramifications.

e. The cables and interconnections, in general, are marginal and introduce noise at the slightest hardware degradation or instrumentation insertion.

f. There is a grounding problem at Langerkopf identified by measurement and discussed in the team chiefs letter.(High impulse noise getting in the test equipment).

g. There may be a grounding problem at Bann. (High noise in some instrumented readings).

<u>Step 12.</u> TEP Report

The TEP report should be considerably different from the report now submitted. The information resulting from the ten basic steps should form the heart of the report. Section III, is an example of the approach and technical discussion needed.(Of course, the author's explanation of the approach should not be included). Any generalized observations based upon not only the specific link analysis, but others, are completely appropriate.

The specific figure inclusions include:

a. LOS path calculations

b. Tabulated extracted link data (Table 2-1)

c. Receiver quieting curves (standard for equipment type and as measured)

d. Receiver AGC curve (standard for equipment type and as measured)

e. ICN vs baseband loading vs NPR curve (Figure 3-4)

f. RSL distribution curve

g. Link performance results (Figure 3-5)

h. Summary of link status (Figure 3-6)

The 11th basic step should be brief, but include all major conclusions concerning the status of the 5 link element, and resolve the question of acceptable link engineering.

Major O&M problems that impact or limit DCS system performance should be stated. O&M problems that have no effect upon DCS users are not appropriate.

The summary of link status as displayed in Figures 3-5, and 3-6, will be included. Data relating to "as found," and post-TEP should be presented. The same pre and post-TEP data should also be plotted on a Figure 3-4 type chart.

The last of the report is the bound set of standard measurements.

Appendix A

Derivation of ICN vs Baseband Loading vs NPR Curves

Explanation for the Idle channel noise vs baseband loading vs NPR curve that is used to derive Equivalent Fully Loaded Baseband Idle Channel Noise performance.

I. Introduction

Early work in analyzing the TEP reports disclosed what was generally obvious to all personnel familiar with the scientific aspects of TEP - the links were routinely greatly degraded. The degradations were grouped into three general categories:

a. The first includes problems suitable for correction on site, such as receiver sensitivity, transmitter output, excess noise in the equipment, and other hardware associated problems for which there are simple corrective actions, and for which there is test equipment.

b. The second covers such problems as wave guide losses, antennae alignments and path obstructions where the difficulty is easy to observe, but normally not within the capability of the site to repair.

c. The third class of problem is the most debilitating to the DCS. These are the adjustment problems such as the transmitter linearity, receiver IF bandpass receiver discriminator linearity, receiver gain/limiter IF group delay, and on occasions, wave guide problems. These are problems that the site can address and correct in part but not'by the numbers' application of the tech order. These class problems require a systems grasp - as contrasted with a box orientation.

As the TEP teams begin each link characterization, the most obvious first category of hardware problems, are measured and corrected. The basic noise floor may not be proper, the receiver quieting curves may not be correct, etc., but in general, these predominantly noise problems are attack. The second category of RF signal strength related problems are not always present, but when they are, they are nearly always identified and quantized correctly.

The third class of problem is the one that receives negligible attention by the site personnel. Unfortunately, the TEP teams do not always correct the problems either. They do, however, measure, assess, and document the results of the problems. The IF bandpass is measured - although it may be 2 MHz off set, the discriminator curve is plotted - but permitted to reverse slope within the IF band pass, the NPR is compensated in loop-back - and consequently degraded in link,etc. Clearly this third category of problems is not being addressed adequately either by the site or addressed in sufficient depth by the TEP teams.

Obviously, then, considerable attention was directed to the analysis of this area during this contract. The following discussion covers the rational, the developing logic, descriptive figures, and the final composite format to relate the key link performance parameters, to absolutely assess and quantize any significant adjustment and nonlinearity difficulties present in the link.

II. Discussion

During the analysis of the TEP reports, a study was made of a number of NPR related factors. One such examination covered the NPR vs baseband loading curve. Figure A-1, is typical of the LC-4.

Note the small circle at NPR=55 db and full CCIR baseband loading. This is the proper point for the curve to maximize. In this case, as with nearly all radios, the peak was less than 55 db, and displaced to the left - that is the curves peak at less than full CCIR loading, and at full load gave NPR's of 45 to 49 db - <u>after TEP.</u>

Figure A-2, shows the displacement envelope of the LC-4, and the FM 8000 radios. It obvious that the FM 8000 radios are either better or are easier to adjust, since the remaining

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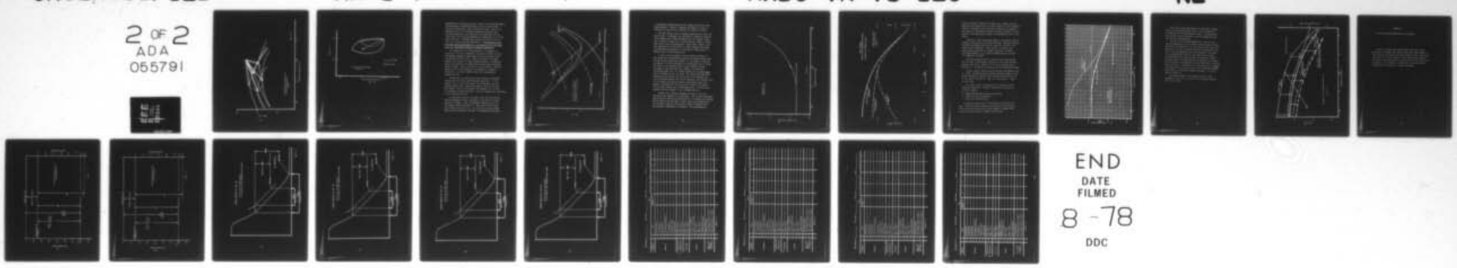

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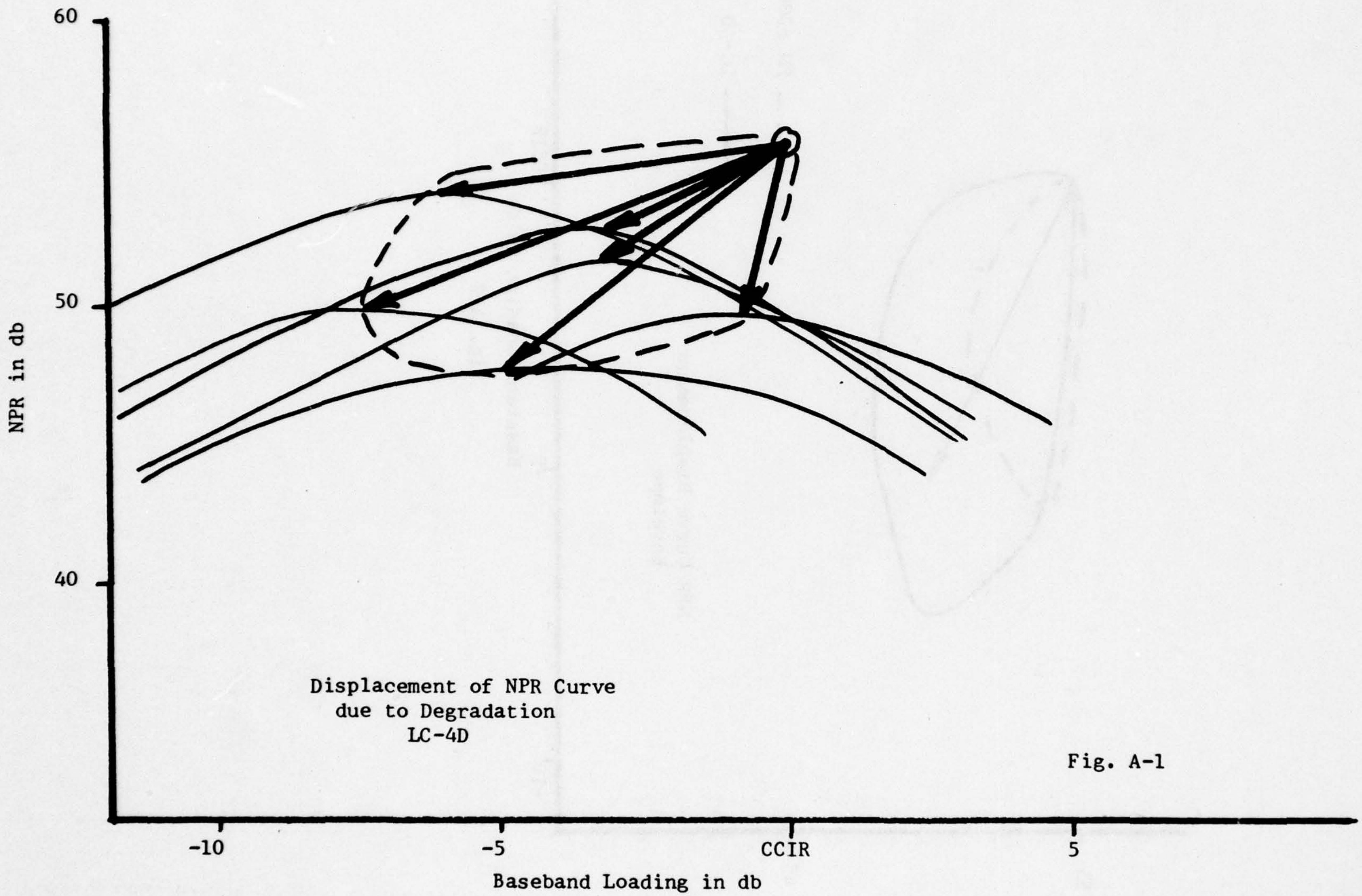


Displacement of NPR Curve
due to Degradation
LC-4D

Fig. A-1

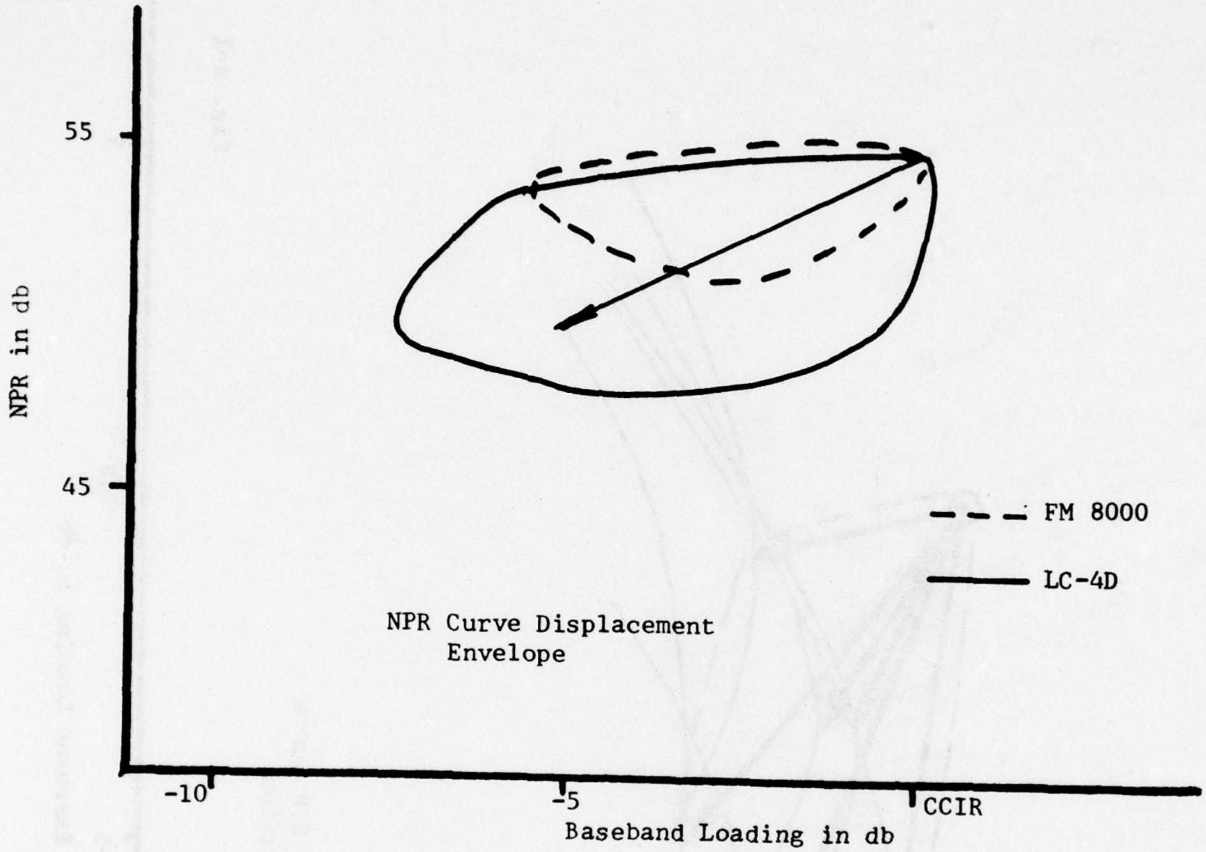

55
45
NPR in db
FM 8000
LC-4D
NPR Curve Displacement Envelope
-10
-5
CCIR
Baseband Loading in db

Fig. A-2

degradations are significantly less. Recall that these performance envelopes depict the NPR performance after the site and TEP teams have completed all their corrective actions. This is the starting point for the inexorable degradation sequence that initiates immediately upon departure of the TEP team, and continues until the accumulated degradation approximates 15 to 20 db, below 'like new.' This NPR decay has been studied in this contract for FM radios carrying FDM signals. The relevance to the FM radios carrying TDM signals is not identical, but the impact will be measurable although by different parameters.

The explanation of the NPR degradation is displayed in Figure A-3. As would be expected, the poorer the NPR, the lower the baseband loading to achieve equal noise contribution from the intermod and basic noise. Thus, the minimum on the NPR loading curve occurs at a lower baseband loading. The deterioration not corrected by the TEP teams is nearly always intermodulation related. Thus, the links are not returned to 'like new' status, and it is an adjustment, an alignment, a linearity difficulty - not basic hardware noise, that predominantly degrades the DCS.

The NPR curve is normally derived by varying the baseband loading above and below the CCIR design load point. In this approach, all of the channel signal levels are equal, and the channel signals vary in exactly the same db ratio as the baseband signal. This is the standard test approach, but it does not reproduce or relate directly to real life operational conditions, on an in-service DCS link.

In operational service, the signal level for each channel remains unchanged at about -13 dbmØ, but the number of active channels is reduced. Thus, the baseband loading is down, but the channel signal levels are not. This type of NPR vs baseband loading curve is not run - but this is the type of information of more interest to the DCS. Few academic institutions

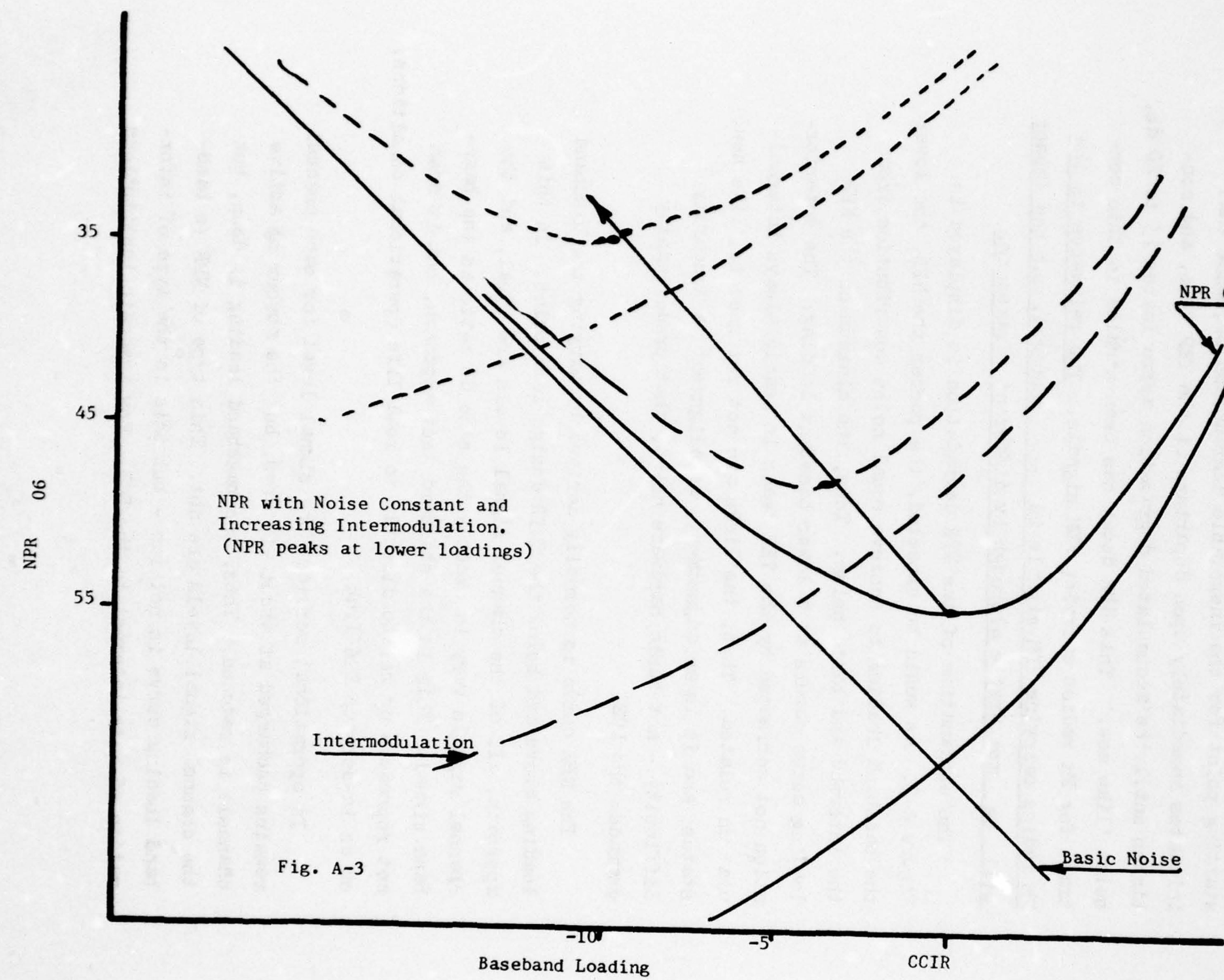

35
45
55
NPR 06
NPR with Noise Constant and
Increasing Intermodulation.
(NPR peaks at lower loadings)
NPR Curve
Intermodulation
Basic Noise
-10
-5
CCIR
Baseband Loading

Fig. A-3

or commercial organizations have ever examined this more interesting approach. Marconi of England and Lenkurt are two exceptions, although neither developed the concept in detail.

The idle channel noise vs baseband loading curve, where the signal level is unchanged, but the number of channels is reduced is not shaped like conventional NPR curves, but assume a shape such as shown in Figure A-4. The publications, however, caution that these curves are approximate! These curves, however, show that channels do not get noisier at light loadings even though the NPR measured performance in this lightly loaded region is reduced below the CCIR design point.

A curve of more interest is the one shown in Figure A-5. This shows the intermodulation products vs baseband loading when the per channel loading is constant, but the number of channels is reduced. The curve displayed is a generalized one, but shows the value of the intermod noise at light baseband loading. The shape of the curve near full loading is the same as a conventional NPR curve. At lighter loadings the intermod ratio will be different in the two cases. The conventional NPR curve approaches more and more the noise floor of the hardware with an ever reducing signal level so the sig/noise will approach zero. In the constant per channel loading, the sig/noise ratio will approach the BINR ratio, and thus, will be about 3 db quieter at very light loading than at CCIR design load. The curve will degrade even more steeply in the overloaded portion.

The NPR curve, however, assesses only part of the link. The other major element is the multiplex. The two major parameters describing the variation in performance of a multiplex with loading are the same as for the radio - basic noise and intermodulation. In the case of the mux, the intrinsic noise is basically flat, and generally independent of frequency. The intermodulation

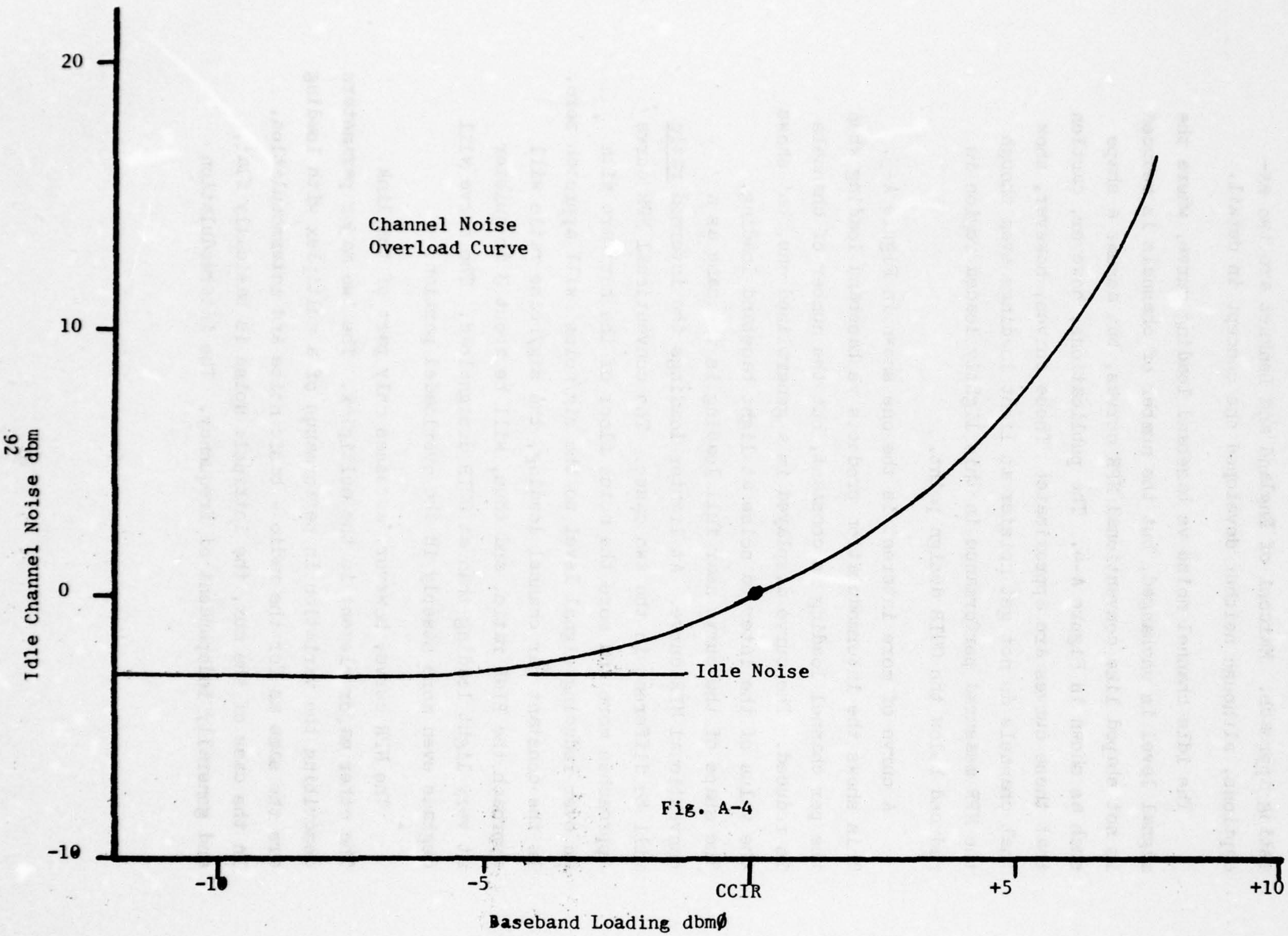

Channel Noise
Overload Curve
Idle Noise
Idle Channel Noise dbm
20
10
0
-10
-10
-5
CCIR
+5
+10
Baseband Loading dbmØ

Fig. A-4

RADIO BASEBAND
CHANNEL NOISE VS BASEBAND LOADING
at
CONSTANT PER CHANNEL LOADING

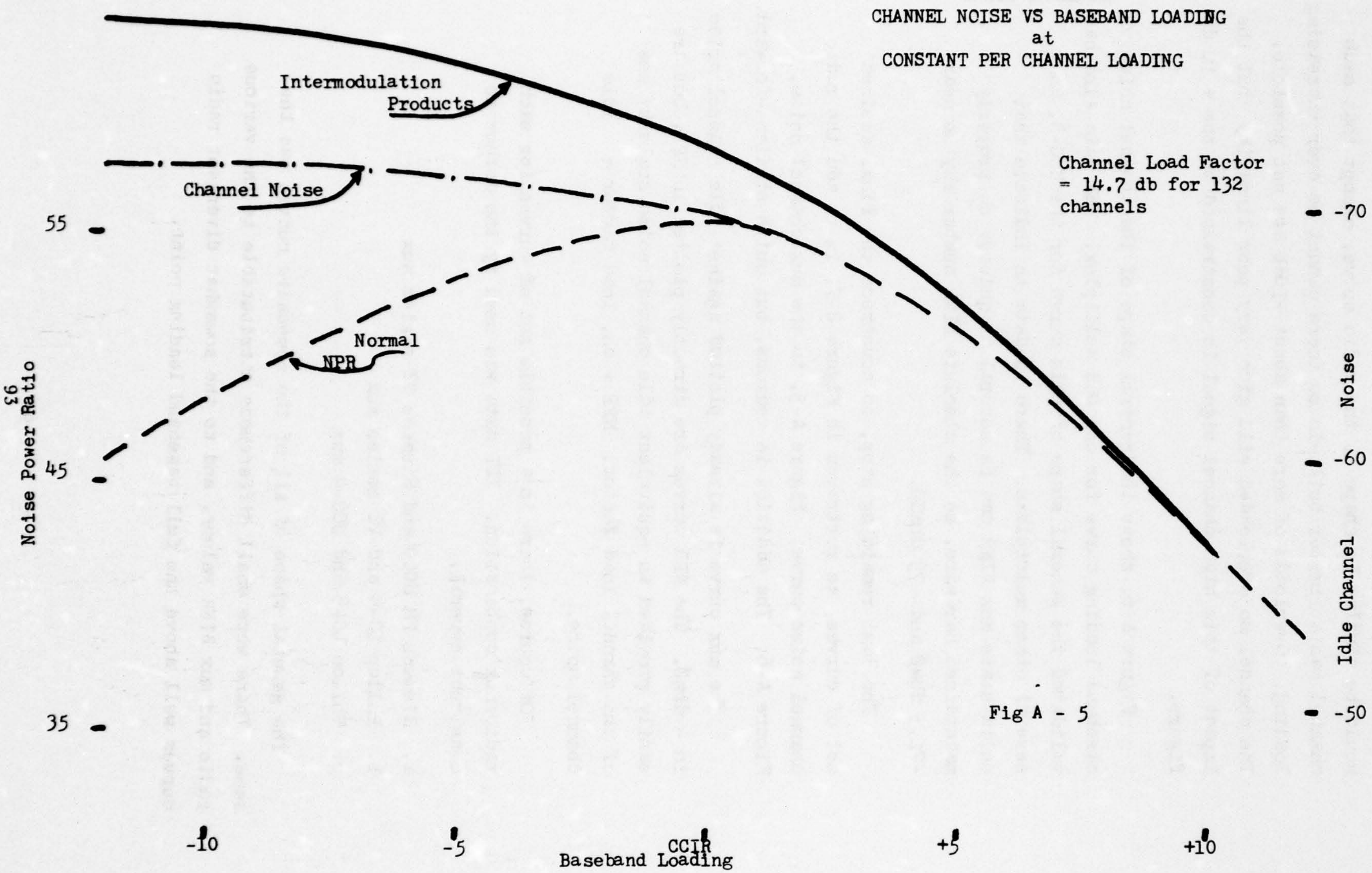


Fig A - 5

would be similar in shape to the radio curve, except that each channel has a limiter built-in so there cannot be ever increasing loading. Overloads of more than about +10db are not possible. The channel so overloaded will give very poor linearity, but the impact of this high channel signal is constrained to the + 10 db figure.

Figure A-6, shows the general shape of the channel noise vs baseband loading curve for one DCS multiplex. TEP data also has validated the general shape of this curve for the UCC-4, and several other multiplexs. There is data to indicate that solid state mux BINR can be several db quieter on properly maintained hardware, so the absolute BINR number may be near -71.5 dbmØ and -73 dbmCØ.

The last remaining step, to construct the final desired set of curves, as portrayed in Figure 2-7, is to add the radio channel noise curve, Figure A-5, to the mux channel noise, Figure A-6. The addition is tedious, but quite straight-forward.

The mux curve is already plotted against idle channel noise in - dbmØ. The NPR curves are directly plotted in NPR, but are easily provided an equivalent idle channel noise scale by use of the channel load factor. NPR + ch. load factor = idle channel noise.

Of course, there is a possible set of curves for each radio/mux combination. TEP data was used by the author to construct several.

a. Siemens FM 8000 and Siemens VZ series mux
b. Philco LC-4 and VZ series mux
c. Philco LC-8 and UCC-4 mux

The general shape of all of the composite curves was the same. There were small differences attributable to the various radio and mux BINR values, and to the somewhat divergent radio curves well above the full baseband loading point.

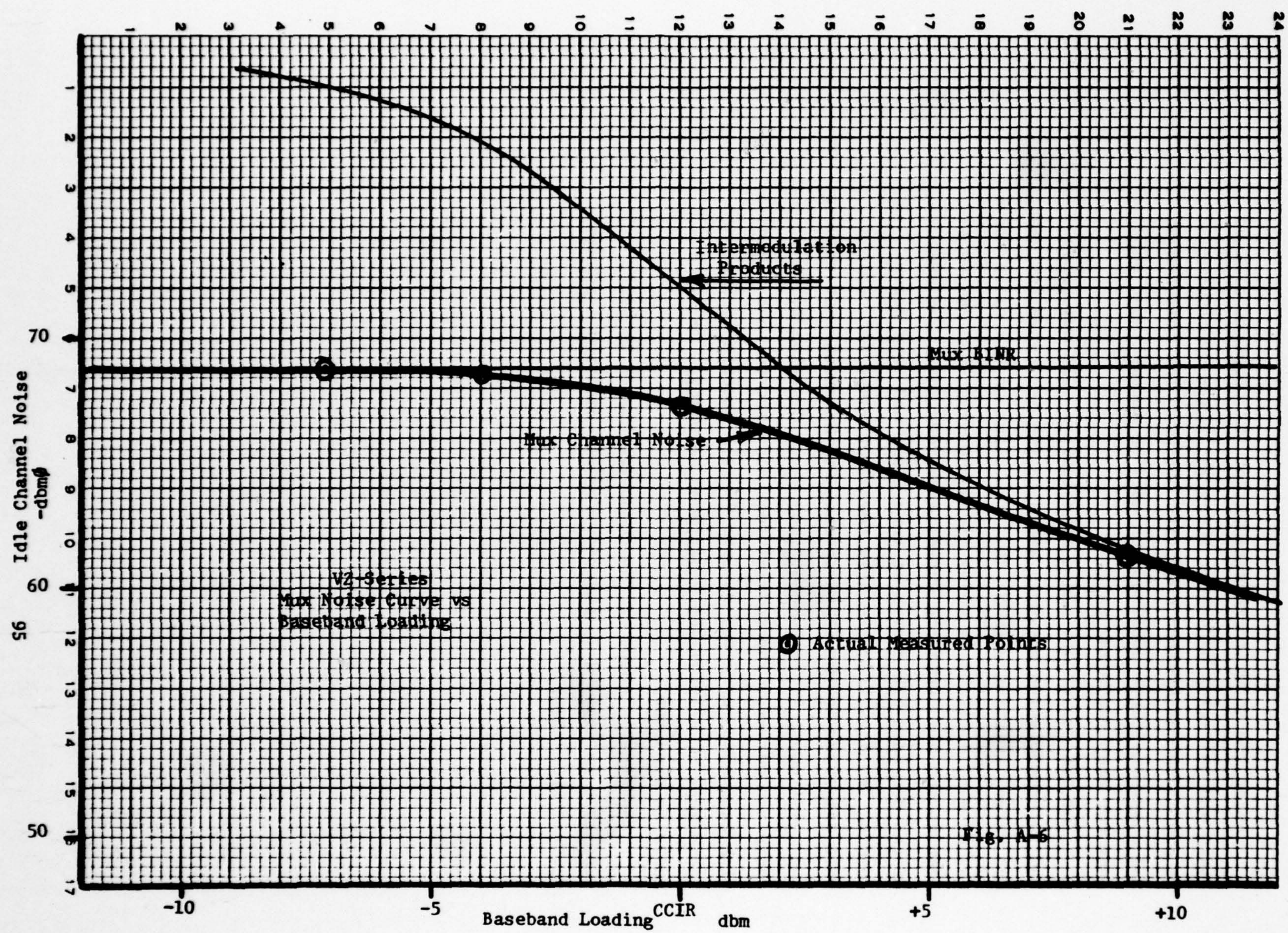
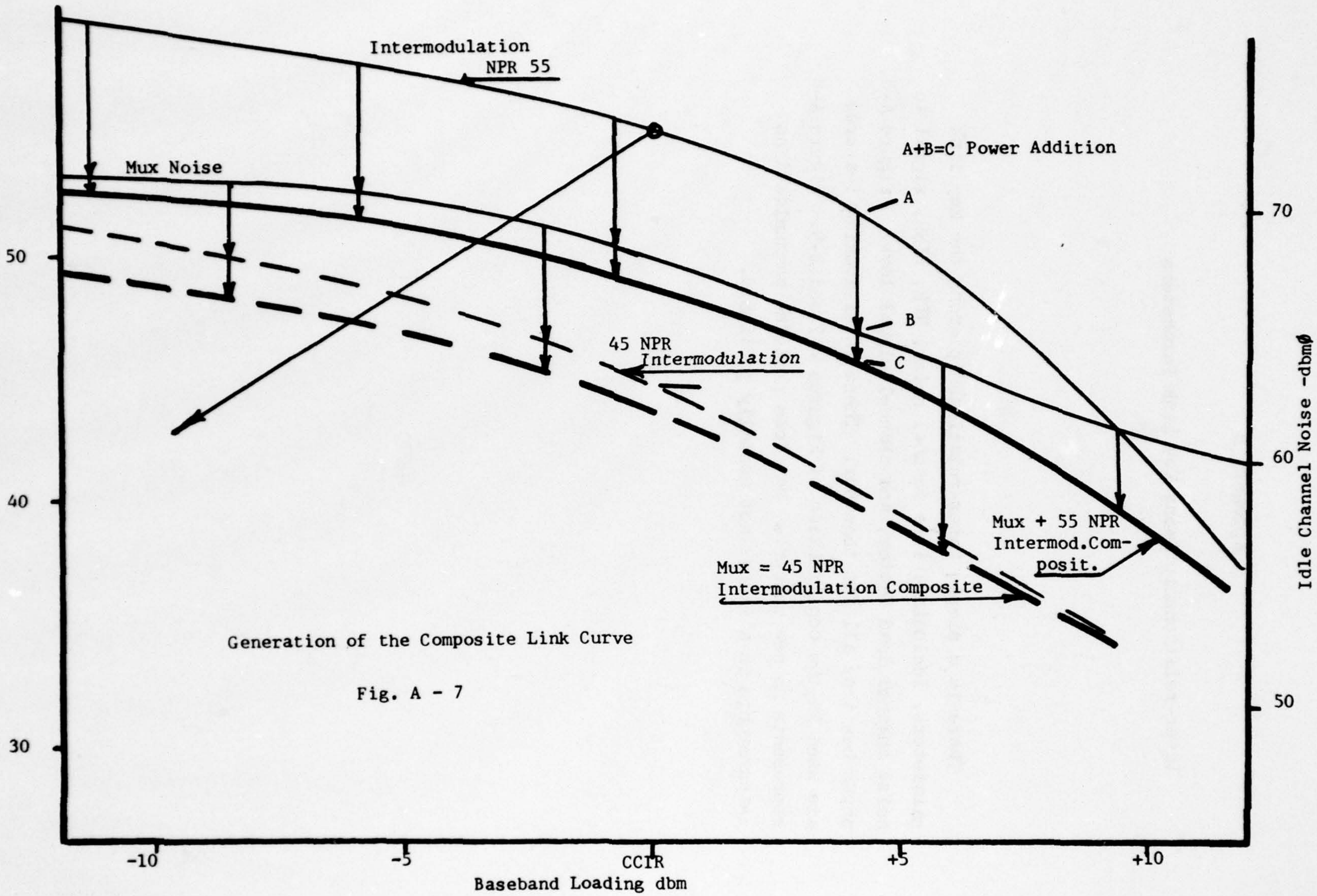

Intermodulation Products
Mux SINR
Mux Channel Noise
V2-Series
Mux Noise Curve vs
Baseband Loading
Actual Measured Points
Idle Channel Noise
-dbm0
70
60
50
-10
-5
+5
+10
Baseband Loading CCIR dbm

Fig. A-6

After the accurate measurement of the properly aligned radio and multiplex hardware, there is little difficulty in producing the desired composite curves. The measurement and composite curve construction need be accomplished only once for each radio/mux pair.

The two curves are added graphically. The mux noise and intermodulation curve is added to the NPR curve for each NPR value, starting with 55 db. The point on the radio curve marked with a circle is moved along the line down and to the left as the NPR degrading curves are addressed. The shape of the degraded NPR curves at very light and very heavy loading deviates from the like new 55 db shape for reasons well described in the SNNPR special Ft. Huachuca test report, and this report is recommended for those desiring to construct their own curves. The special test also proved that a <u>single</u> link composite curve may be used for all acceptably designed radio hops at only slightly degraded accuracy. (± 2.5 db would be expected)

The generic shape of the composite curves is well displayed in Figs. 2-7, and 3-4, for all baseband loadings CCIR +3 db or less.



Generation of the Composite Link Curve

Fig. A - 7

Appendix B

Inter-relationship Among Key Link Parameters

There is a simple inter-relationship among the key link parameters, including; idle channel noise, NPR, BINR, signal to noise channel load factor, and channel signal level. Figure A-8, shows how they all fit together. These inter-locking features are used in the construction of Figures 2-7 and 2-9. Figure A-8, represents no new concepts, but does plot the communications measurements in a manner not normally published.

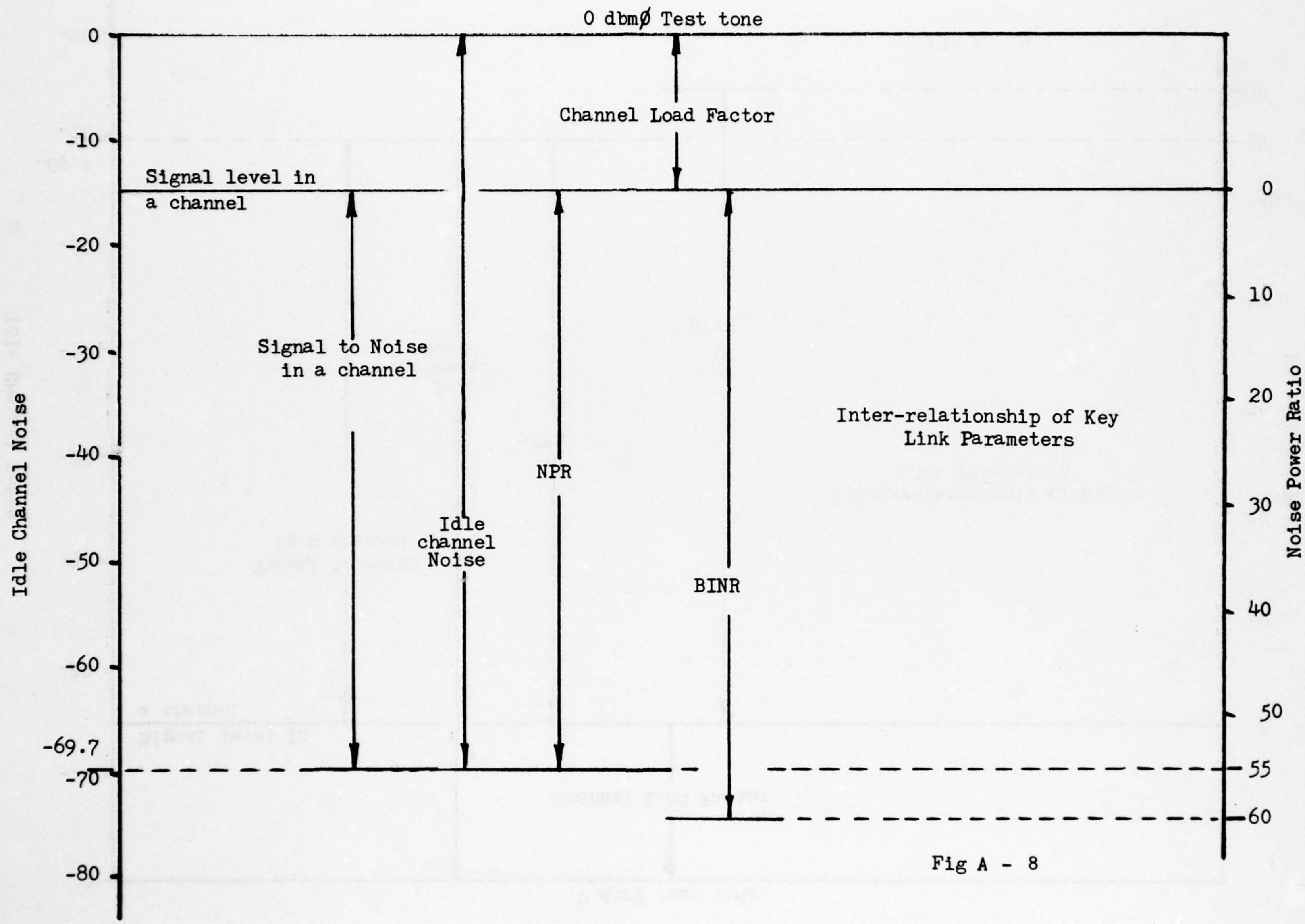

0 dbmØ Test tone
Channel Load Factor
Signal level in
a channel
Signal to Noise
in a channel
Idle
channel
Noise
NPR
BINR
Inter-relationship of Key
Link Parameters
Idle Channel Noise
0
-10
-20
-30
-40
-50
-60
-69.7
-70
-80
Noise Power Ratio
0
10
20
30
40
50
55
60

Fig A - 8

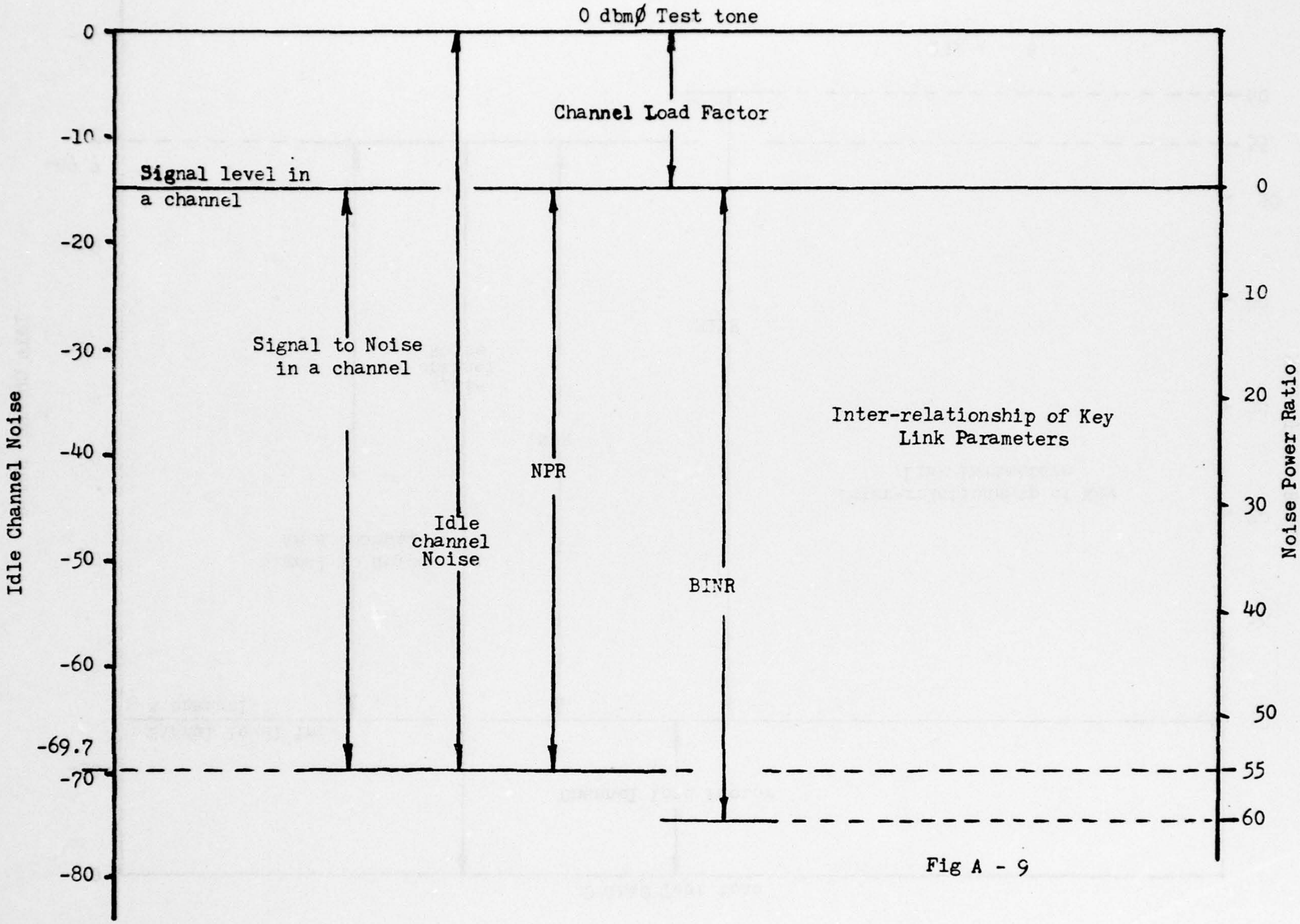

0 dbmØ Test tone
Channel Load Factor
Signal level in a channel
Signal to Noise in a channel
Idle channel Noise
NPR
BINR
Inter-relationship of Key Link Parameters
Idle Channel Noise
0
-10
-20
-30
-40
-50
-60
-69.7
-70
-80
Noise Power Ratio
0
10
20
30
40
50
55
60

Fig A - 9

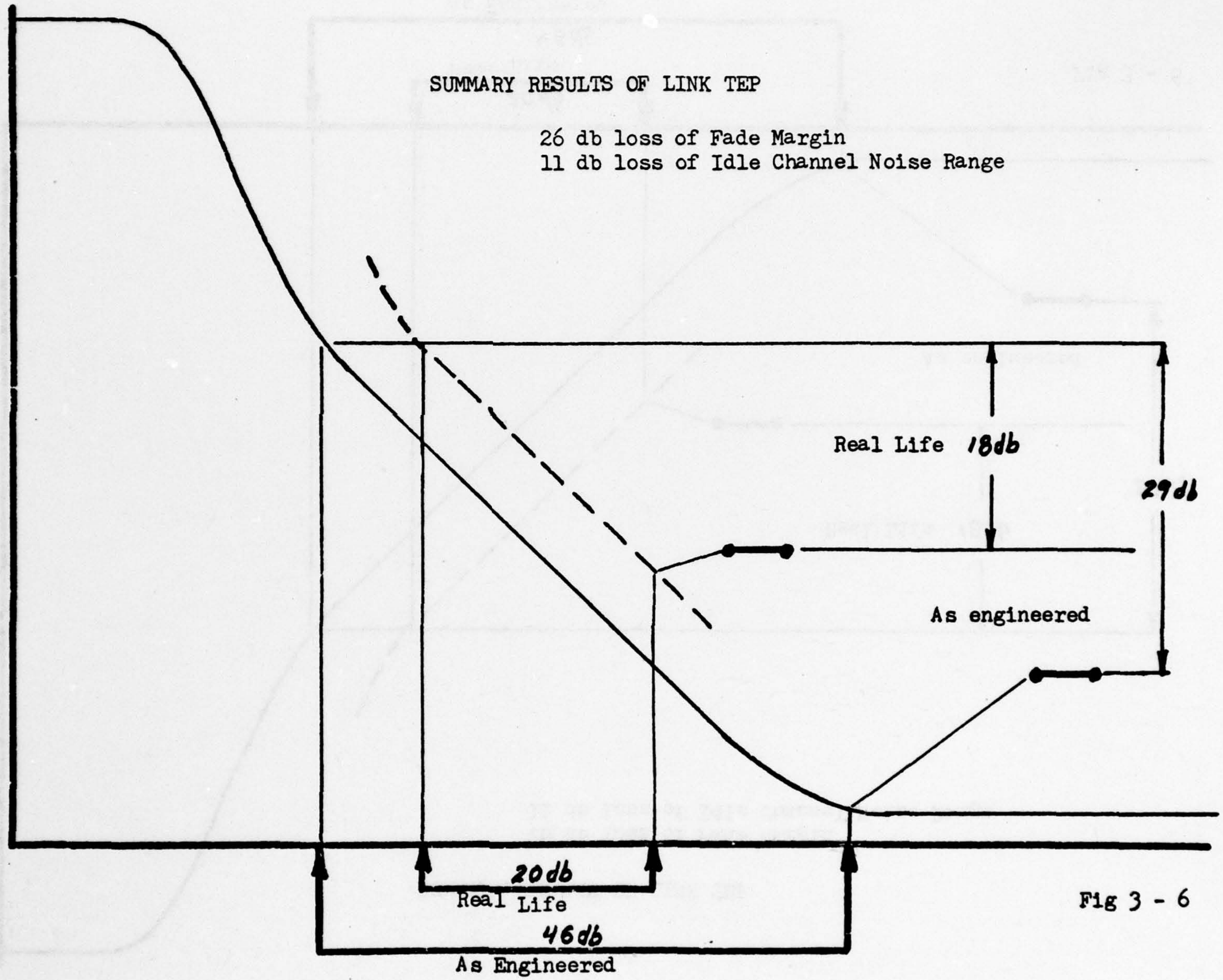
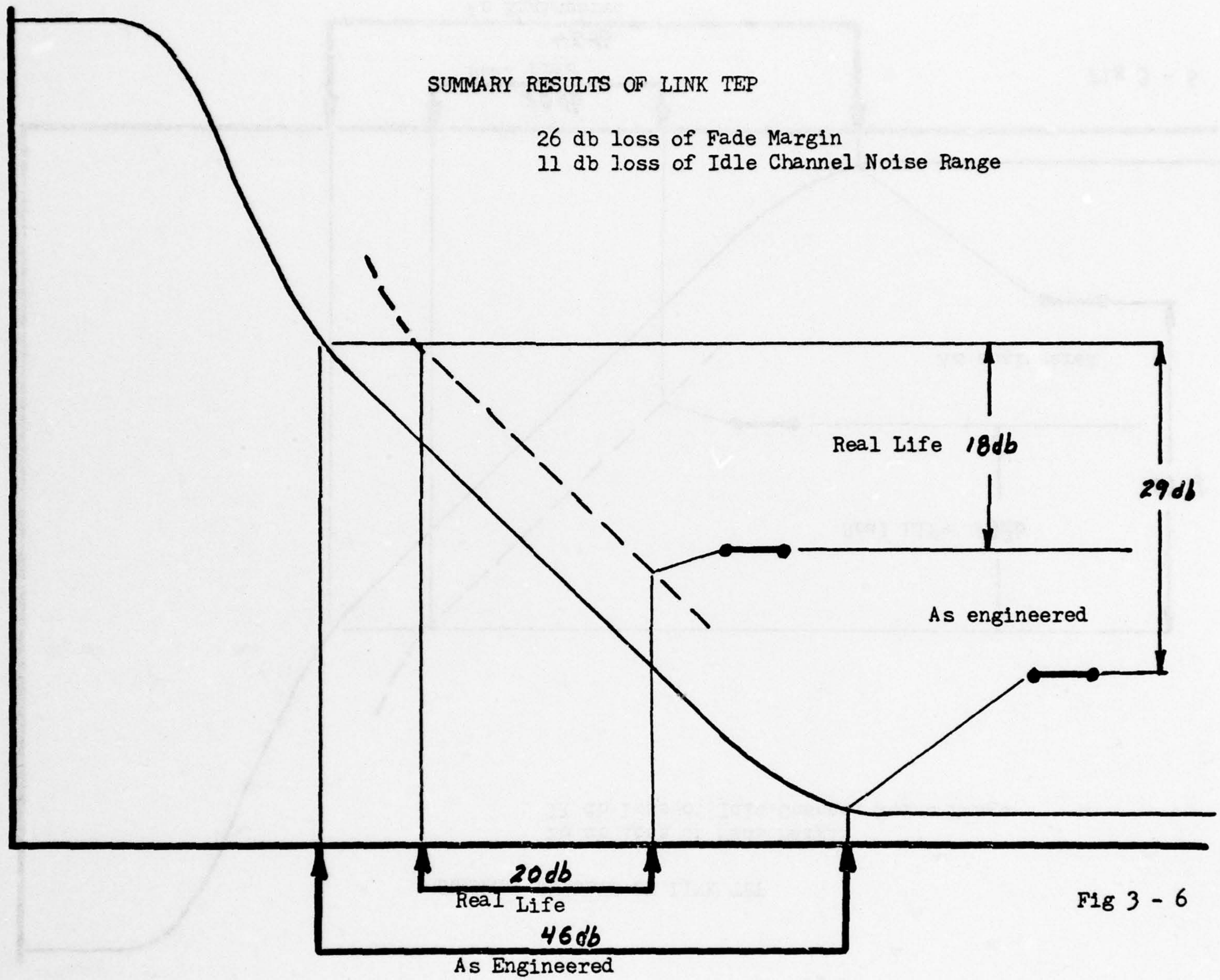
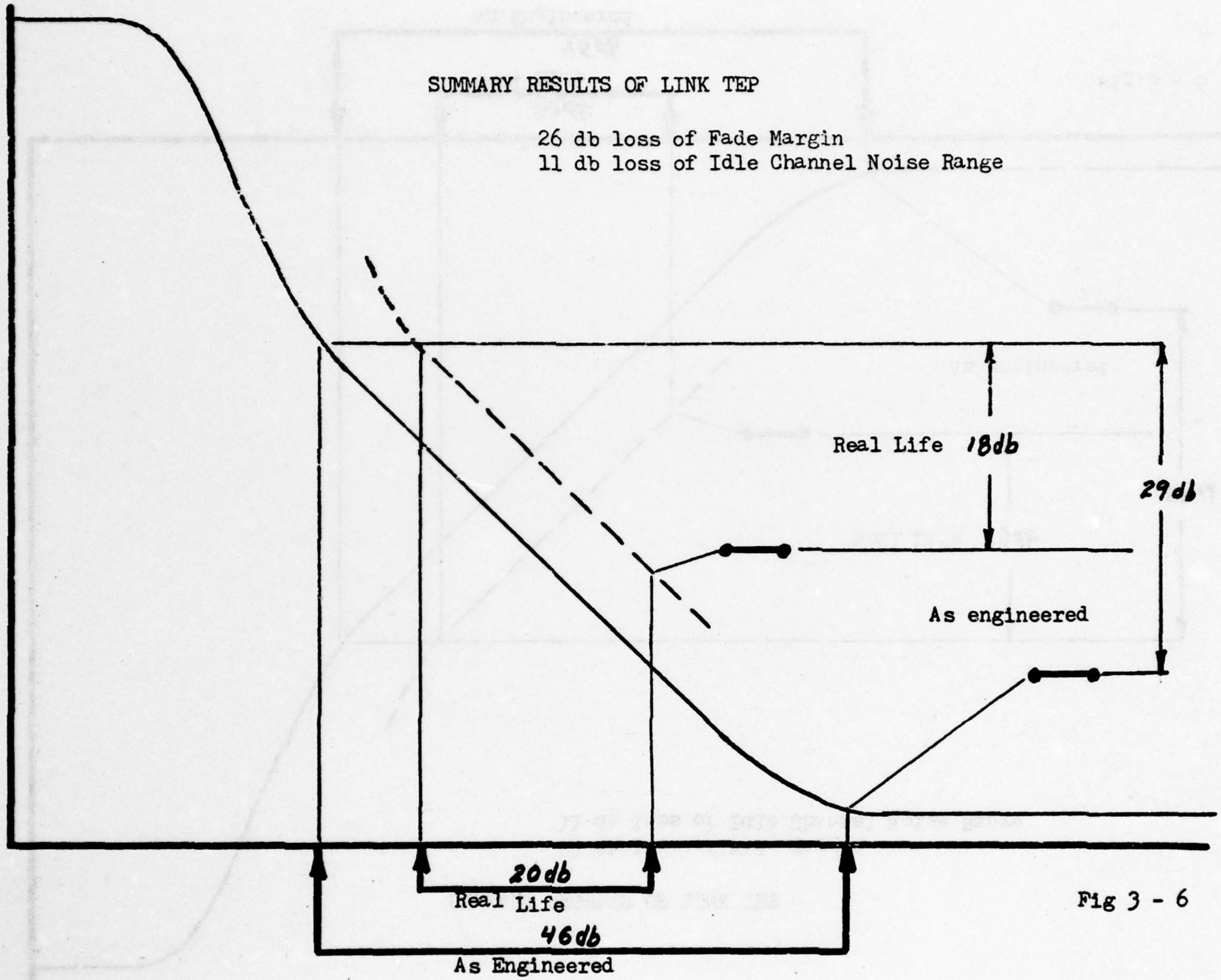

SUMMARY RESULTS OF LINK TEP
26 db loss of Fade Margin
11 db loss of Idle Channel Noise Range
Real Life 18db
29db
As engineered
20db
Real Life
46db
As Engineered

Fig 3 - 6



SUMMARY RESULTS OF LINK TEP
26 db loss of Fade Margin
11 db loss of Idle Channel Noise Range
Real Life 18db
29db
As engineered
20db
Real Life
46db
As Engineered

Fig 3 - 6


SUMMARY RESULTS OF LINK TEP
26 db loss of Fade Margin
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Real Life 18db
29db
As engineered
20db
Real Life
46db
As Engineered

Fig 3 - 6

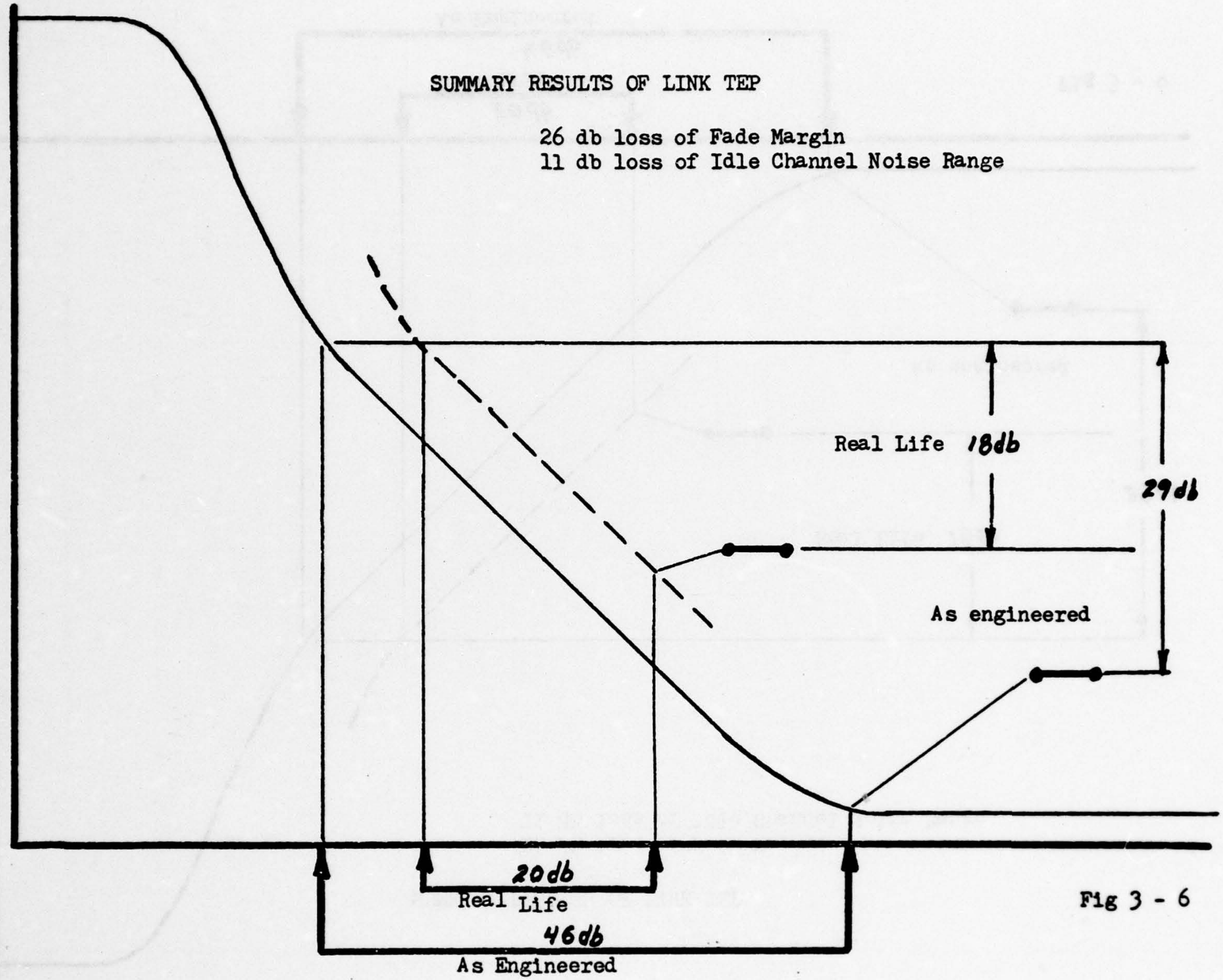
SUMMARY RESULTS OF LINK TEP
26 db loss of Fade Margin
11 db loss of Idle Channel Noise Range
Real Life 18db
29db
As engineered
20db
Real Life
46db
As Engineered

Fig 3 - 6

TEP Report # ________ DCA Link # ________ PMP Link # ________ Dated ________

Element		Item	Calculated Value	Link A	Link B	A	B
Receiver		Noise Figure					
		IF Bandwidth					
		FM Threshold					
		Per Channel Deviation					
		Pre-emphasis					
		Frequency Slots					
		Fully Quieted					
Receiver and Transmitter		NPR (loop)					
		BINR (loop)					
Multiplex		NPR (loop)					
		BINR (loop)					
System		Number of Channels					
		Receive Signal Level					
		NPR (link)					
		BINR (link)					
		Channel Load Factor					
End to End Channel Performance		Baseband Loading					
		Idle Channel Noise (3 KHz)					
		Idle Channel Noise (C msg)					

Table 2 - 1

TEP Report # ________ DCA Link # ________ PMP Link # ________ Dated ________

Element		Item	Calculated Value	Link A	Link B	A	B
Receiver		Noise Figure					
		IF Bandwidth					
		FM Threshold					
		Per Channel Deviation					
		Pre-emphasis					
		Frequency Slots					
		Fully Quieted					
Receiver and Transmitter		NPR (loop)					
		BINR (loop)					
Multiplex		NPR (loop)					
		BINR (loop)					
System		Number of Channels					
		Receive Signal Level					
		NPR (link)					
		BINR (link)					
		Channel Load Factor					
End to End Channel Performance		Baseband Loading					
		Idle Channel Noise (3 KHz)					
		Idle Channel Noise (C msg)					

Table 2 - 1

TEP Report # ________ DCA Link # ________ PMP Link # ________ Dated ________

Element		Item	Calculated Value	Link A	Link B	A	B
Receiver		Noise Figure					
		IF Bandwidth					
		FM Threshold					
		Per Channel Deviation					
		Pre-emphasis					
		Frequency Slots					
		Fully Quieted					
Receiver and Transmitter		NPR (loop)					
		BINR (loop)					
Multiplex		NPR (loop)					
		BINR (loop)					
System		Number of Channels					
		Receive Signal Level					
		NPR (link)					
		BINR (link)					
		Channel Load Factor					
End to End Channel Performance		Baseband Loading					
		Idle Channel Noise (3 KHz)					
		Idle Channel Noise (C msg)					

Table 2 - 1

TEP Report # ____________ DCA Link # ____________ PMP Link # ____________ Dated ____________

Element		Item	Link Calculated Value	A	B	A	B
Receiver		Noise Figure					
		IF Bandwidth					
		FM Threshold					
		Per Channel Deviation					
		Pre-emphasis					
		Frequency Slots					
		Fully Quieted					
Receiver and Transmitter		NPR (loop)					
		BINR (loop)					
Multiplex		NPR (loop)					
		BINR (loop)					
System		Number of Channels					
		Receive Signal Level					
		NPR (link)					
		BINR (link)					
		Channel Load Factor					
End to End Channel Performance		Baseband Loading					
		Idle Channel Noise (3 KHz)					
		Idle Channel Noise (C msg)					

Table 2 - 1